quarterly analysis review

16.4

4Q 2016

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ta engineering	jim moore, charles taylor

5 december 2016

topics

1 energy markets

automotive markets

technologies studies

environmental studies

consumers & opinion surveys

policy & business studies

qar

outline

1 energy markets

gasoline prices

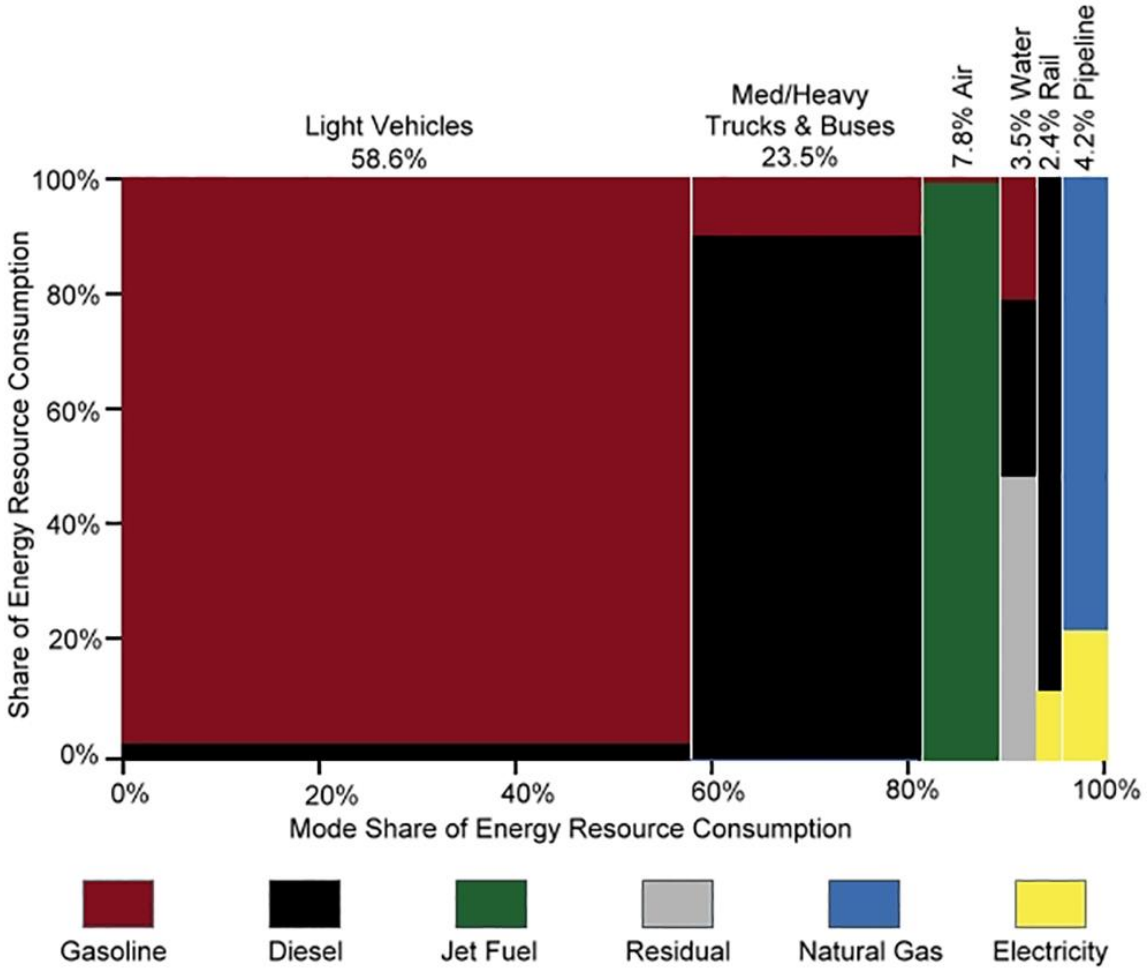
> EIA: Gasoline prices continue to be near lowest levels in a decade
> EIA: Gasoline consumption, VMT at all-time high

oil markets/production

> EIA: Domestic crude oil production down from 2015
> Bloomberg: Cost of drilling dropping worldwide
> OPEC: Plans to curtail oil production in 2017

energy usage

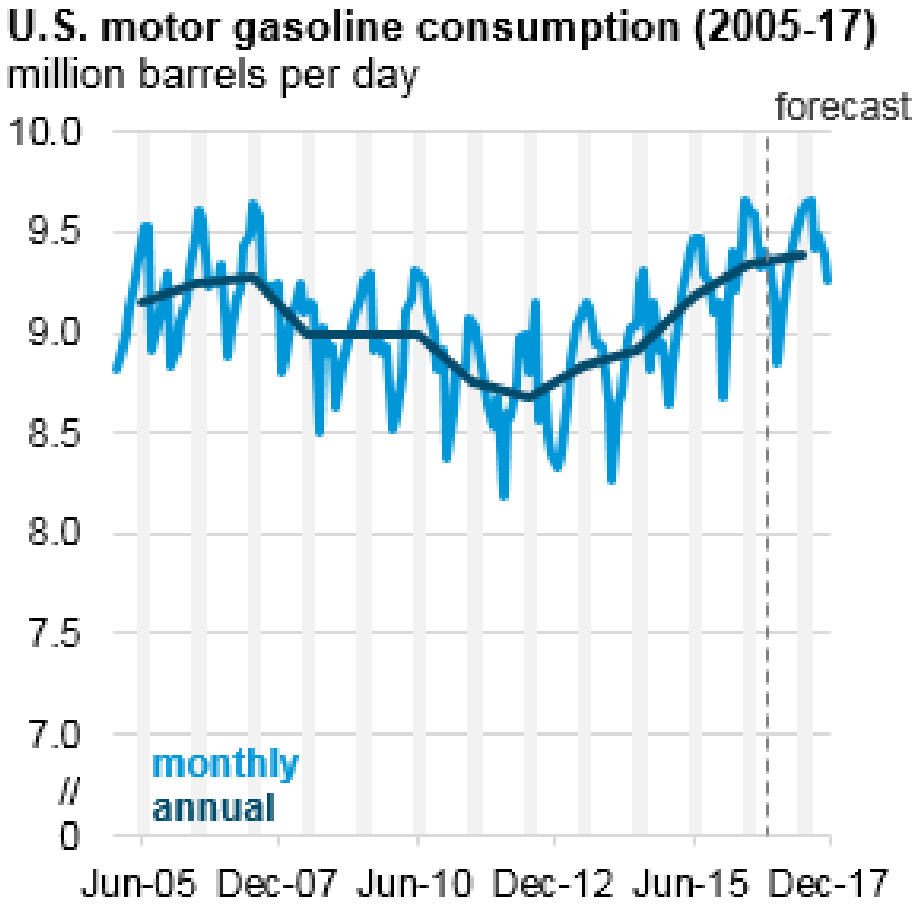
FOTW: On-road transportation consumes more than 80% of transportation energy in United States

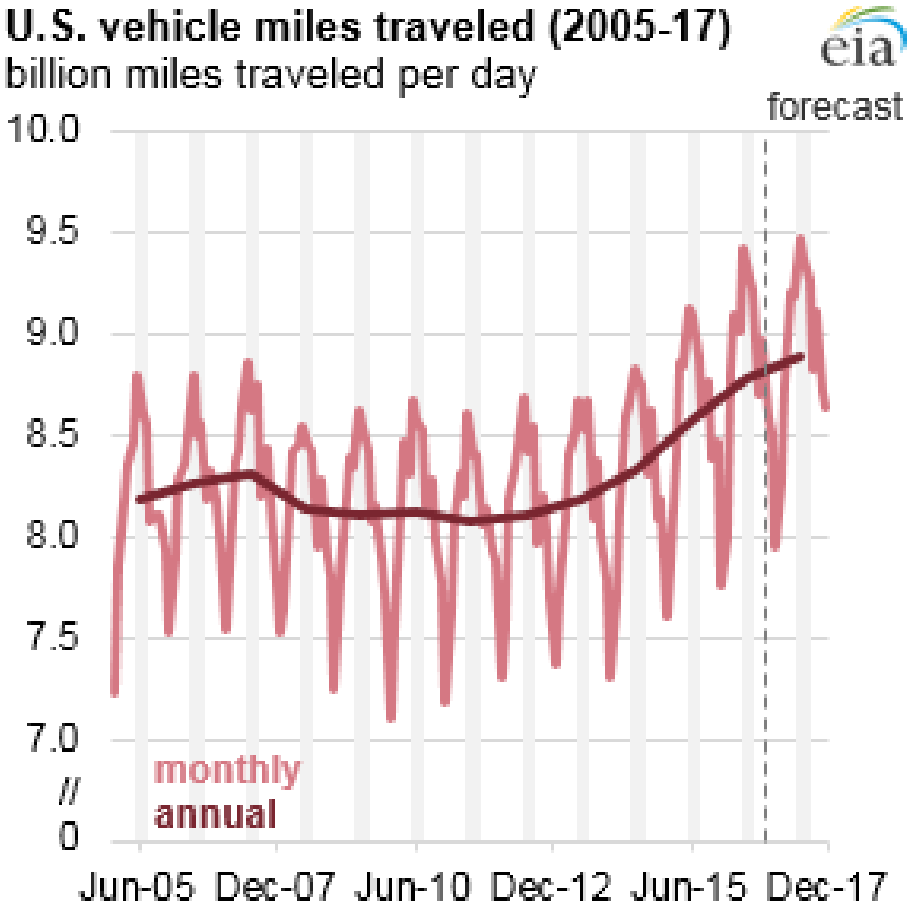


Source: http://energy.gov/eere/vehicles/fact-953-november-28-2016-road-transportation-consumes-more-80-all-transportation

gasoline usage

EIA: Domestic gasoline consumption and vehicle miles traveled (VMT) set new high in summer 2016

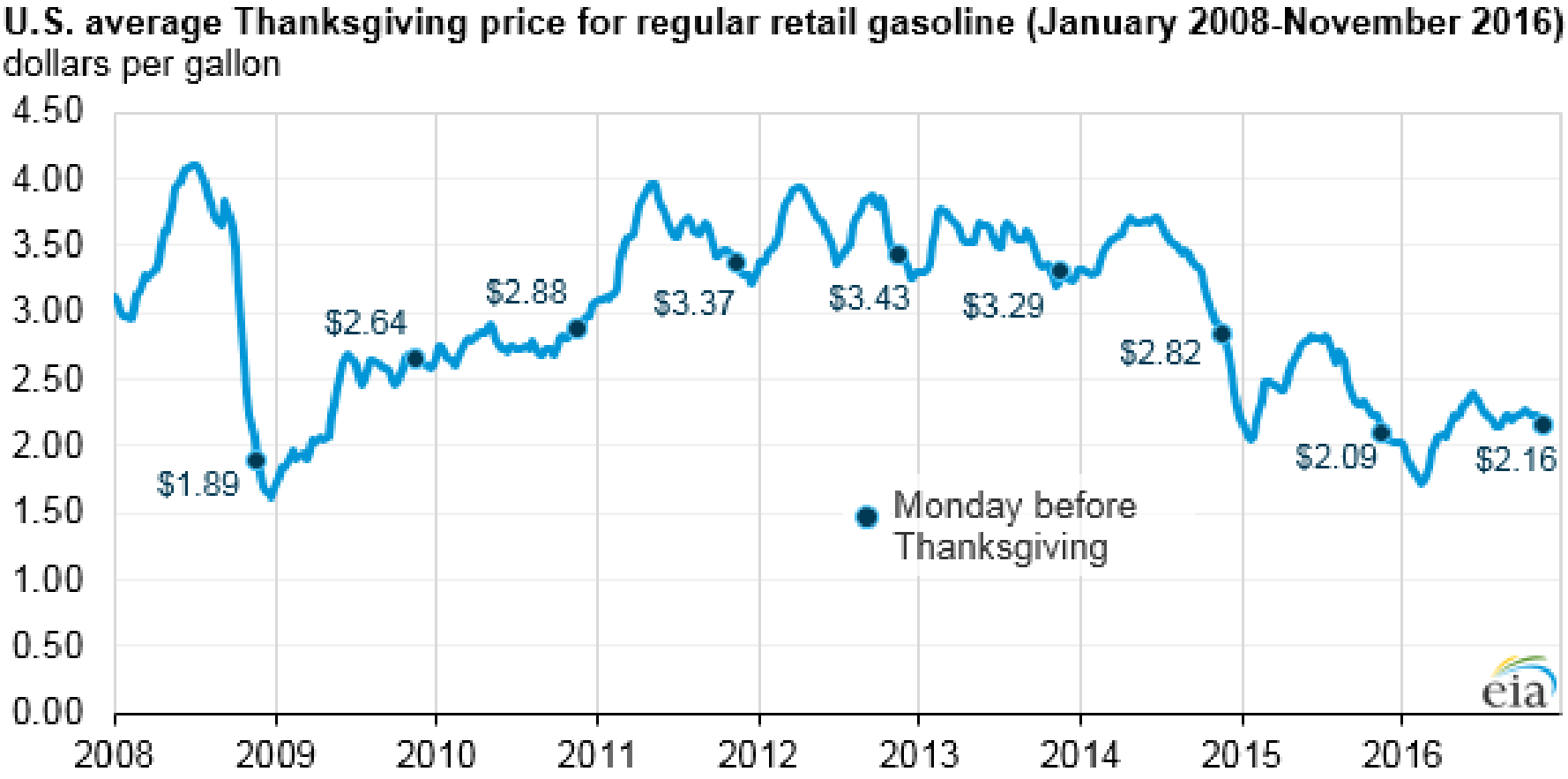




Source: http://www.eia.gov/todayinenergy/detail.php?id=28612

gasoline prices

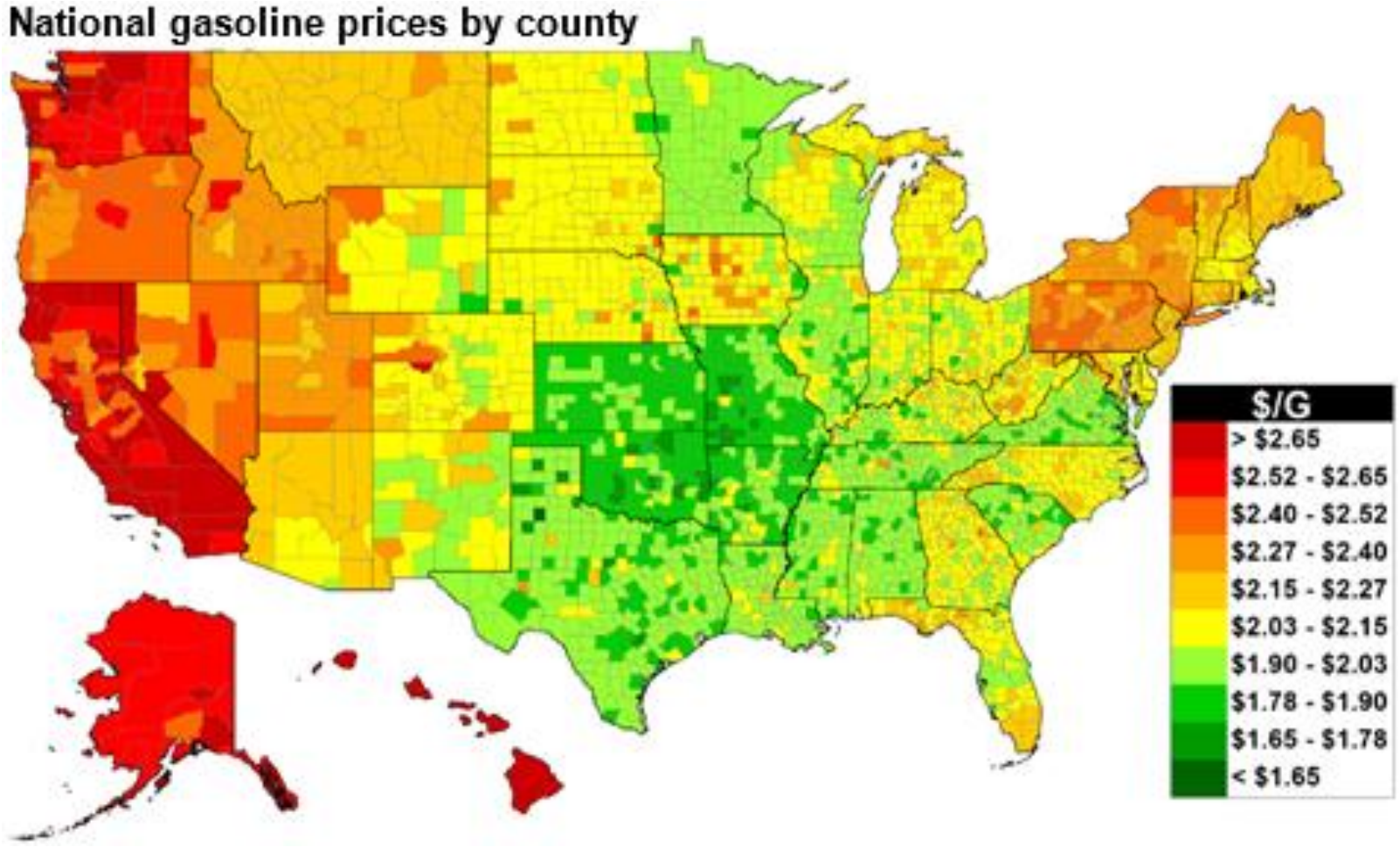
EIA: National gasoline prices second lowest in eight years for Thanksgiving



Source: http://www.eia.gov/todayinenergy/detail.php?id=28892

gasoline prices

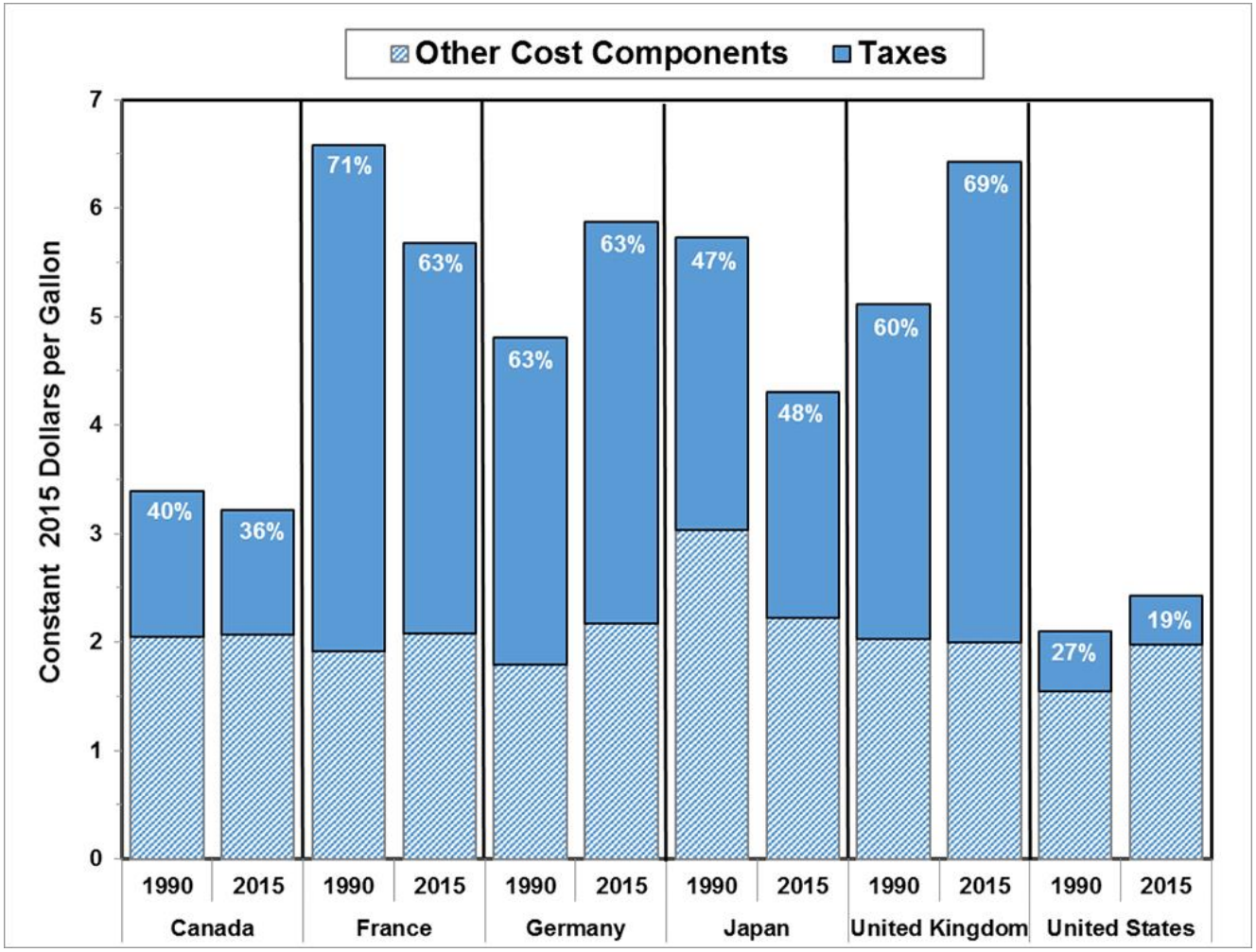
EIA: Gasoline prices vary greatly throughout country, taxes different by state



Source: http://www.eia.gov/todayinenergy/detail.php?id=28892

gasoline prices

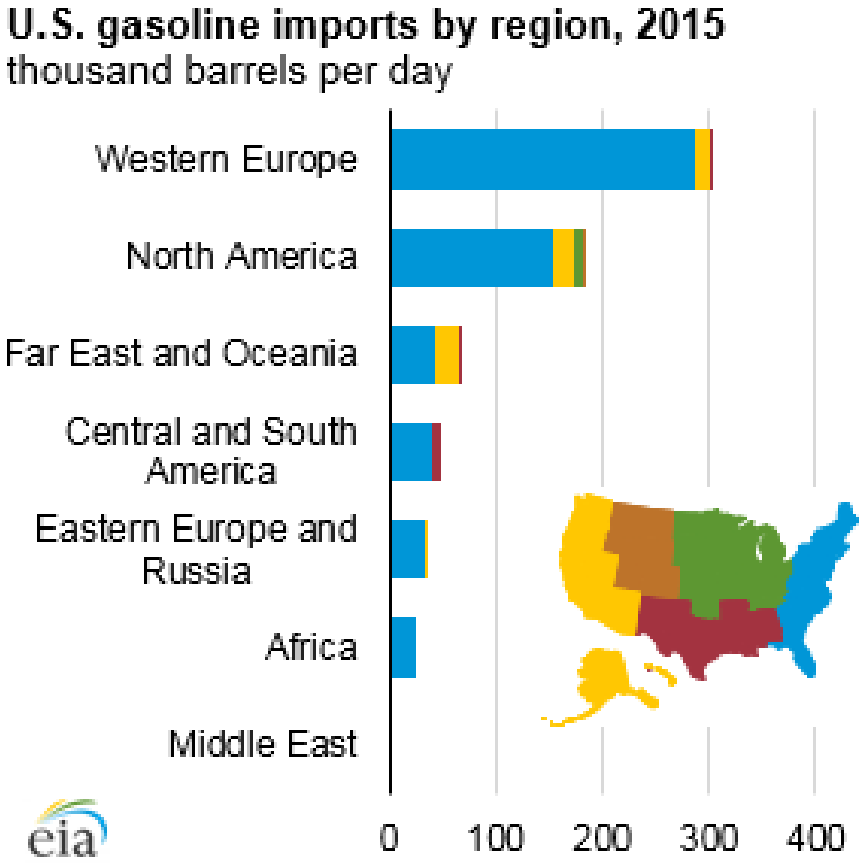
FOTW: Gasoline taxes lower in United States than most other OECD countries (only lower in Mexico)

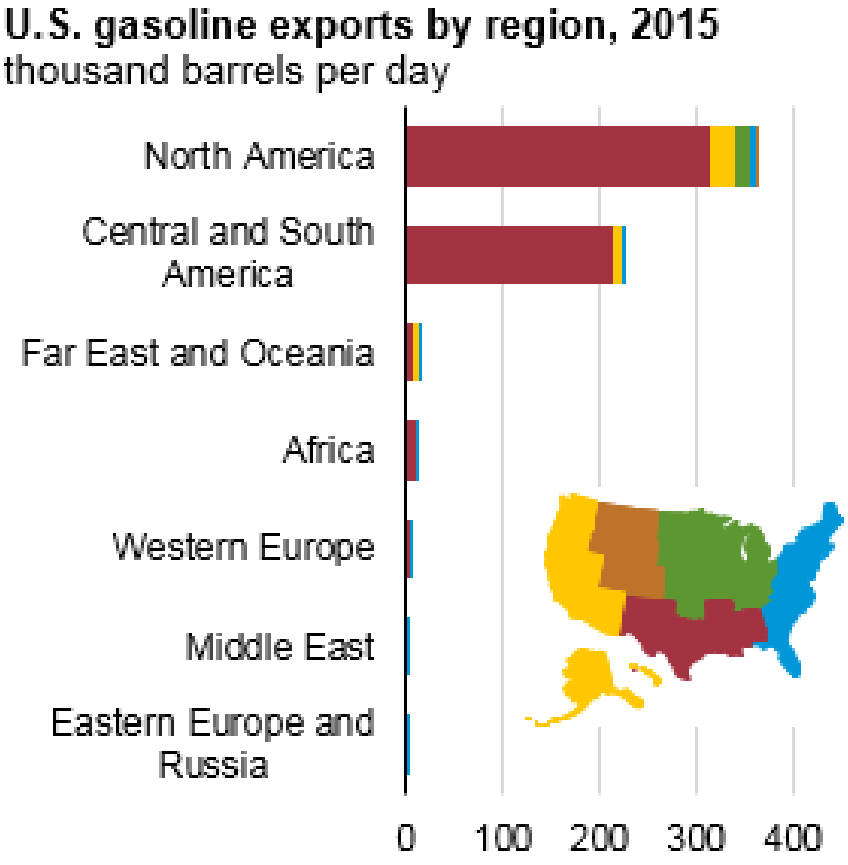


Source: http://energy.gov/eere/vehicles/fact-954-december-5-2016-gasoline-taxes-united-states-were-below-20-total-price-2015

gasoline market

EIA: Gasoline imports and exports vary regionally across United States; imports from Western Europe and Canada, exports to western hemisphere



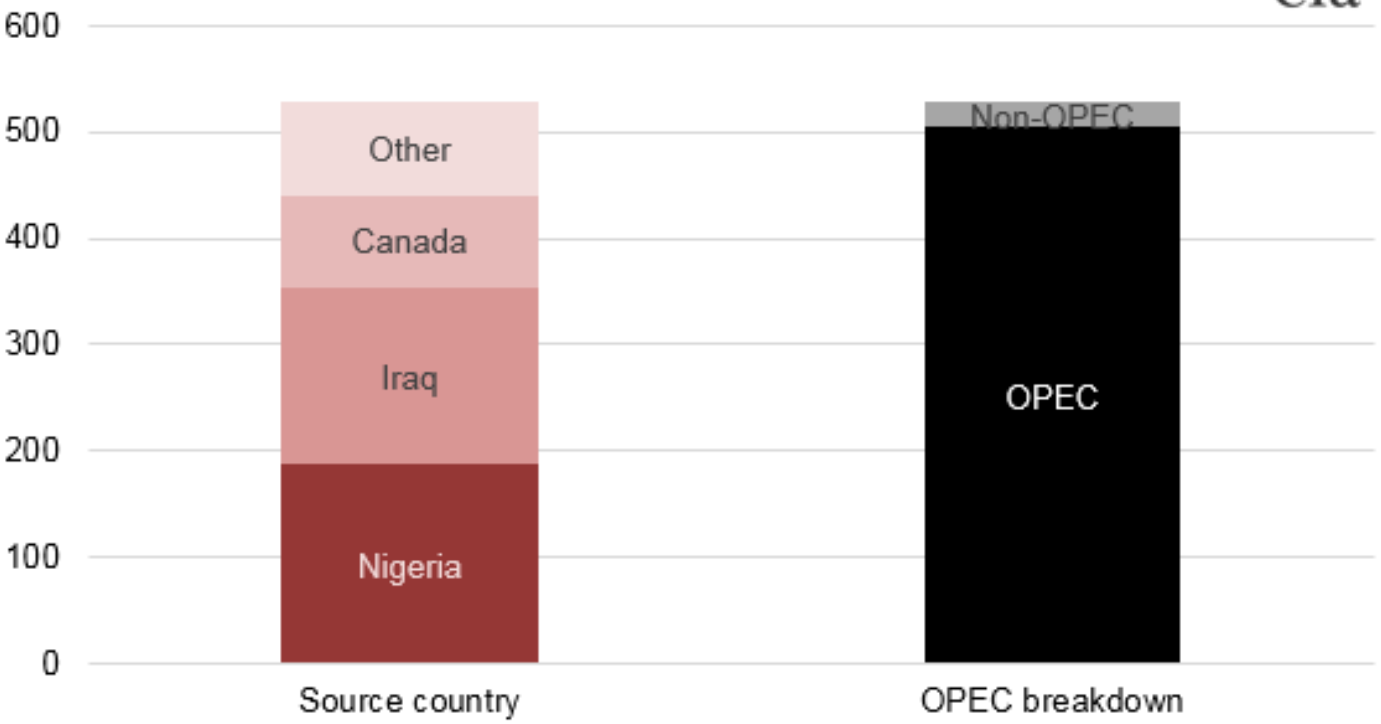


Source: http://www.eia.gov/todayinenergy/detail.php?id=28892

oil markets

EIA: Crude imports increased in early 2016, first increase since 2010, led by Canada and OPEC imports

Figure 2. U.S. crude import growth by source
(1H 2016 vs 1H 2015)
thousand barrels per day

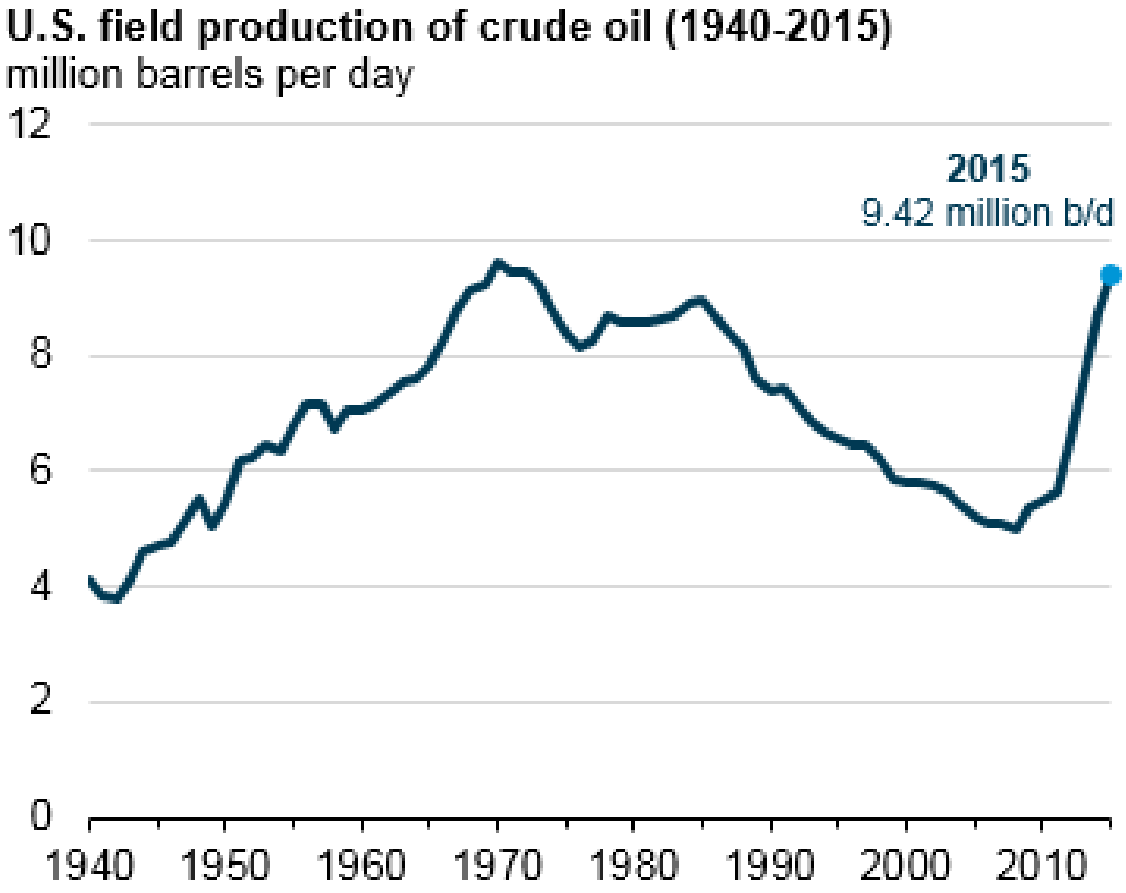


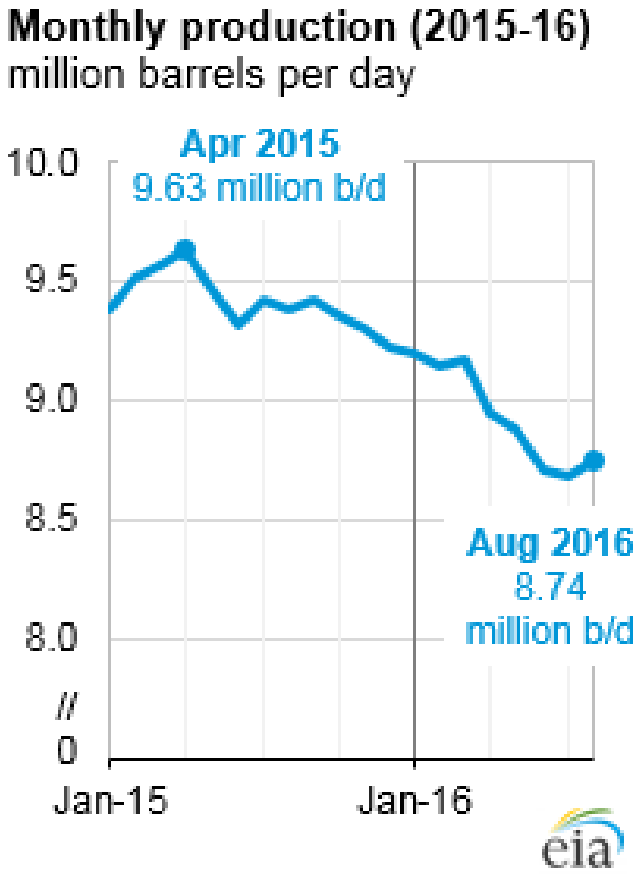
Note: Non-OPEC growth is less than Canadian growth due to declines from other non-OPEC countries.
Source: U.S. Energy Information Administration

Source: http://www.eia.gov/petroleum/weekly/archive/2016/161005/includes/analysis_print.cfm

oil markets

EIA: 2015 U.S. crude oil production highest since 1972; down nearly 10% from high in 2016

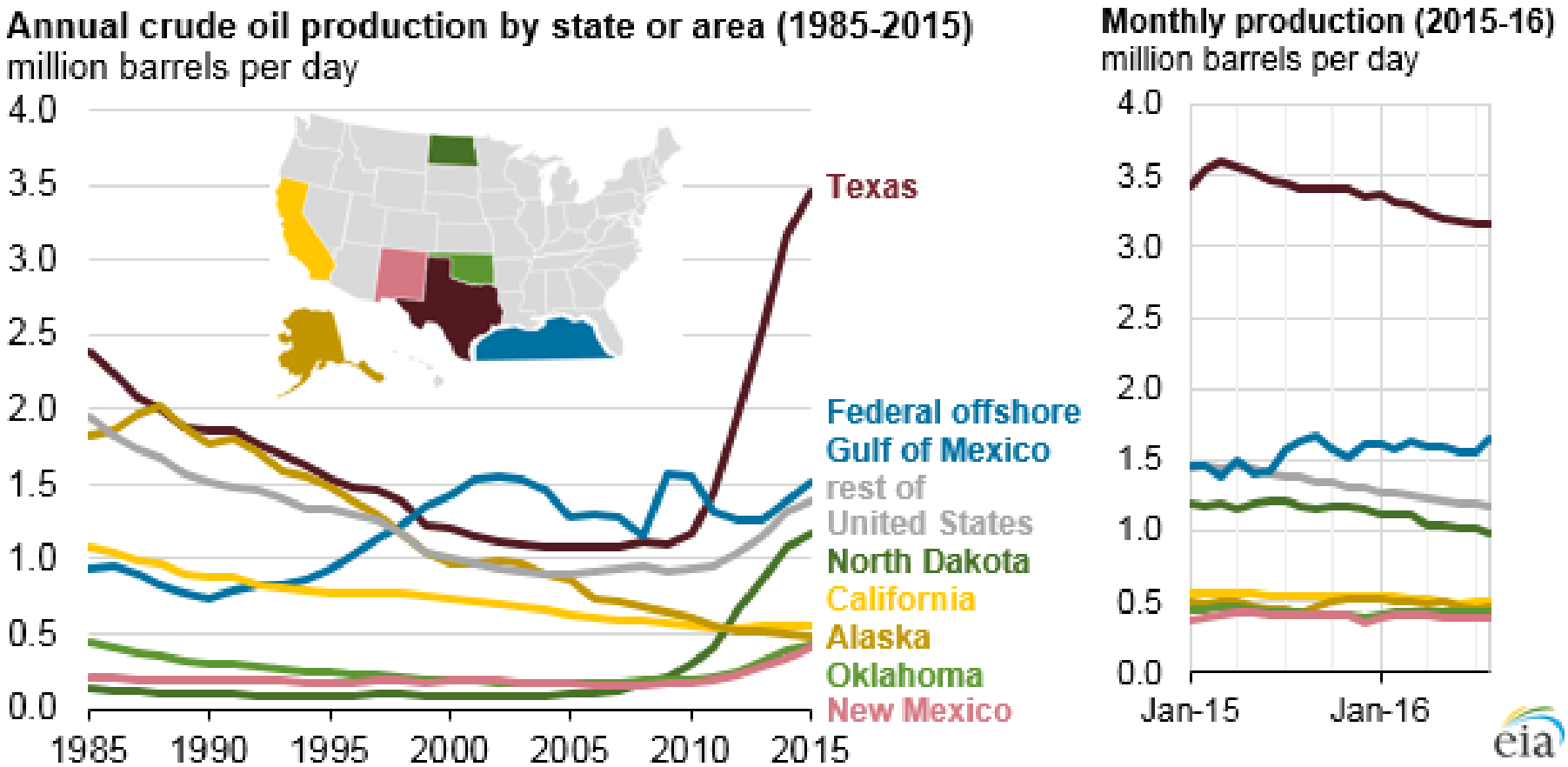




Source: http://www.eia.gov/todayinenergy/detail.php?id=28672

oil markets

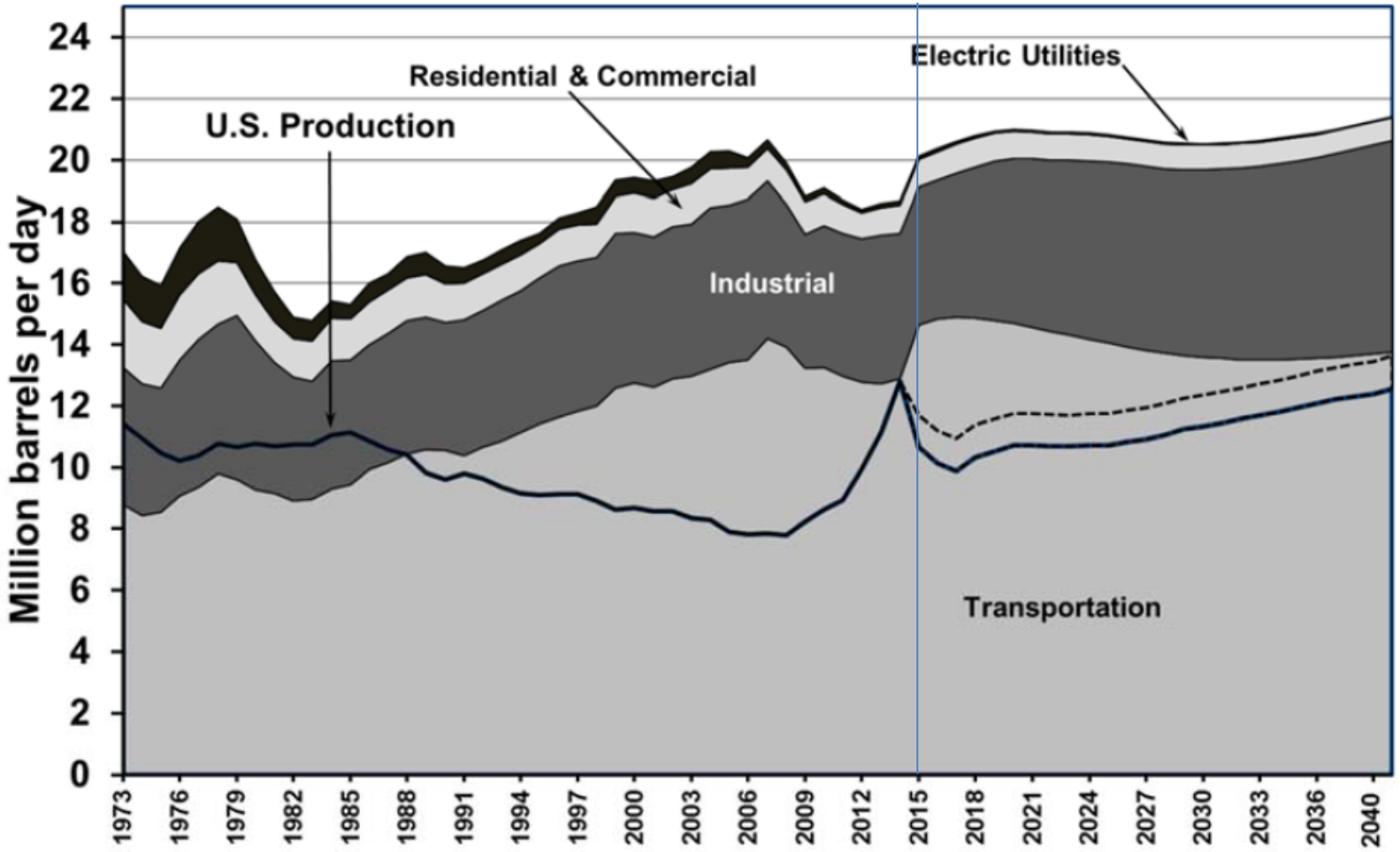
EIA: Outside of Gulf of Mexico offshore drilling, U.S. crude production down in all regions in 2016



Source: http://www.eia.gov/todayinenergy/detail.php?id=28672

oil markets

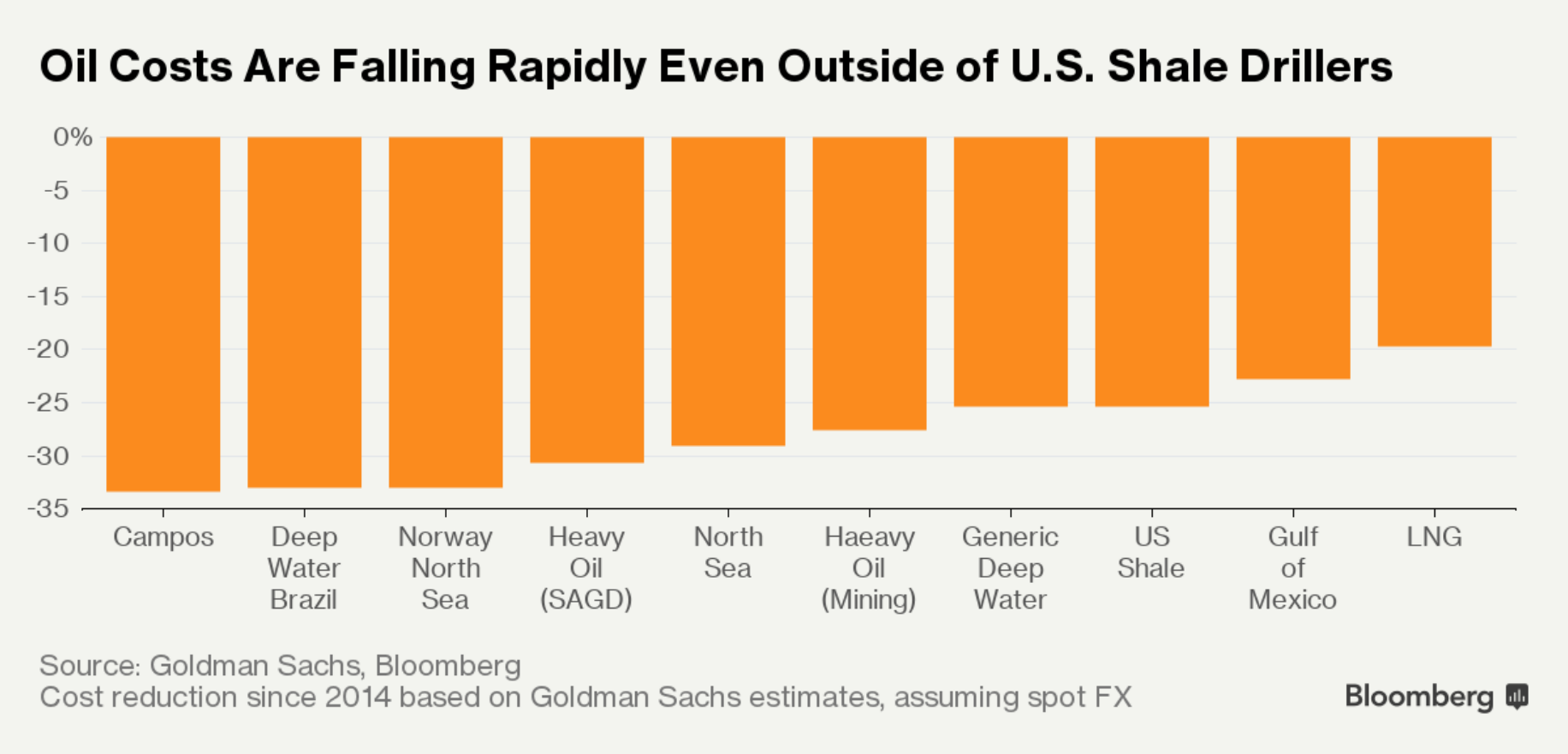
EIA/ORNL: Projections for 2015 show U.S. petroleum production once again below usage in transportation



Source: http://cta.ornl.gov/data/index.shtml Figure 1.5

oil markets

Bloomberg: Cost of drilling dropping worldwide, due to standardization and increased efficiency



Source: http://www.bloomberg.com/news/articles/2016-09-28/how-actual-nuts-and-bolts-are-bringing-down-oil-prices

oil markets

OilPrice, CNBC: Oil production to be limited among OPEC countries, crude oil prices rise on news

Agreed crude oil production adjustments and levels* *(tb/d)*

Member Country	Reference Production level	Adjustment	Production level effective January 2017
Algeria	1,089	–50	1,039
Angola	1,751	–87	1,673
Ecuador	548	–26	522
Gabon	202	–9	193
Indonesia**			
IR Iran	3,975	90	3,797
Iraq	4,561	–210	4,351
Kuwait	2,838	–131	2,707
Libya			
Nigeria			
Qatar	648	–30	618
Saudi Arabia	10,544	–486	10,058
UAE	3,013	–139	2,874
Venezuela	2,067	–95	1,972

Source: http://oilprice.com/Energy/Energy-General/The-OPEC-Deal-Here-Are-The-Details.html and http://data.cnbc.com/quotes/@CL.1

topics

2

energy markets

automotive markets

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policy & business studies

qar

outline

2 automotive markets

LDV market

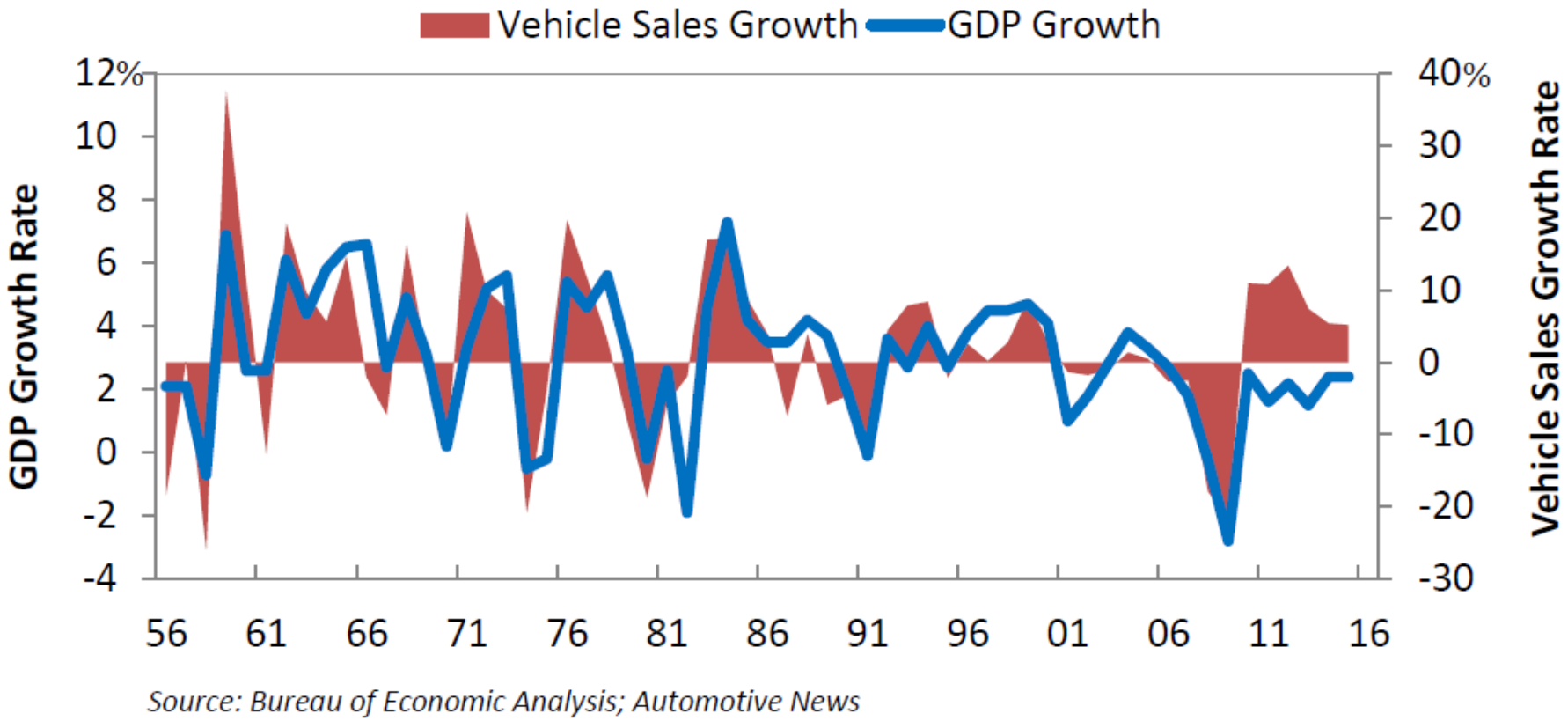
> CAR: Vehicle sales growth historically trends with GDP growth
> CAR: Domestic automakers more focused on pickups than foreign OEMs

EV market

> FOTW: Half-million PEVs sold in United States since 2010
> ANL: EV sales up worldwide
> TØI: BEVs often a second car, PHEVs treated similarly to ICEVs in Norway

LDV market

CAR: Growth in vehicle sales historically well-correlated with growth in GDP

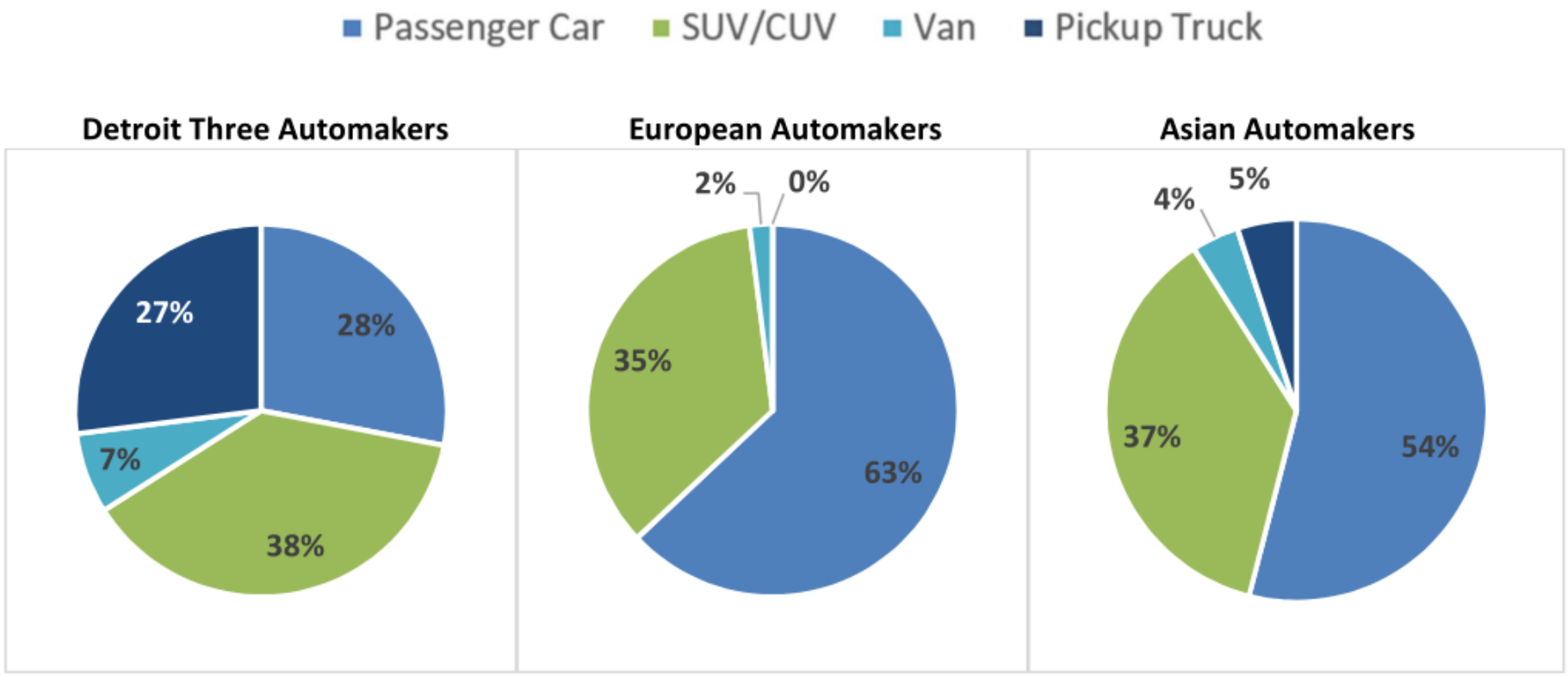


Source: Bureau of Economic Analysis; Automotive News

Source: http://www.cargroup.org/?module=Publications&event=View&pubID=143

LDV market

CAR: Domestic manufacturing split between pickups, cars, and SUV/CUV; for foreign: more cars, fewer trucks

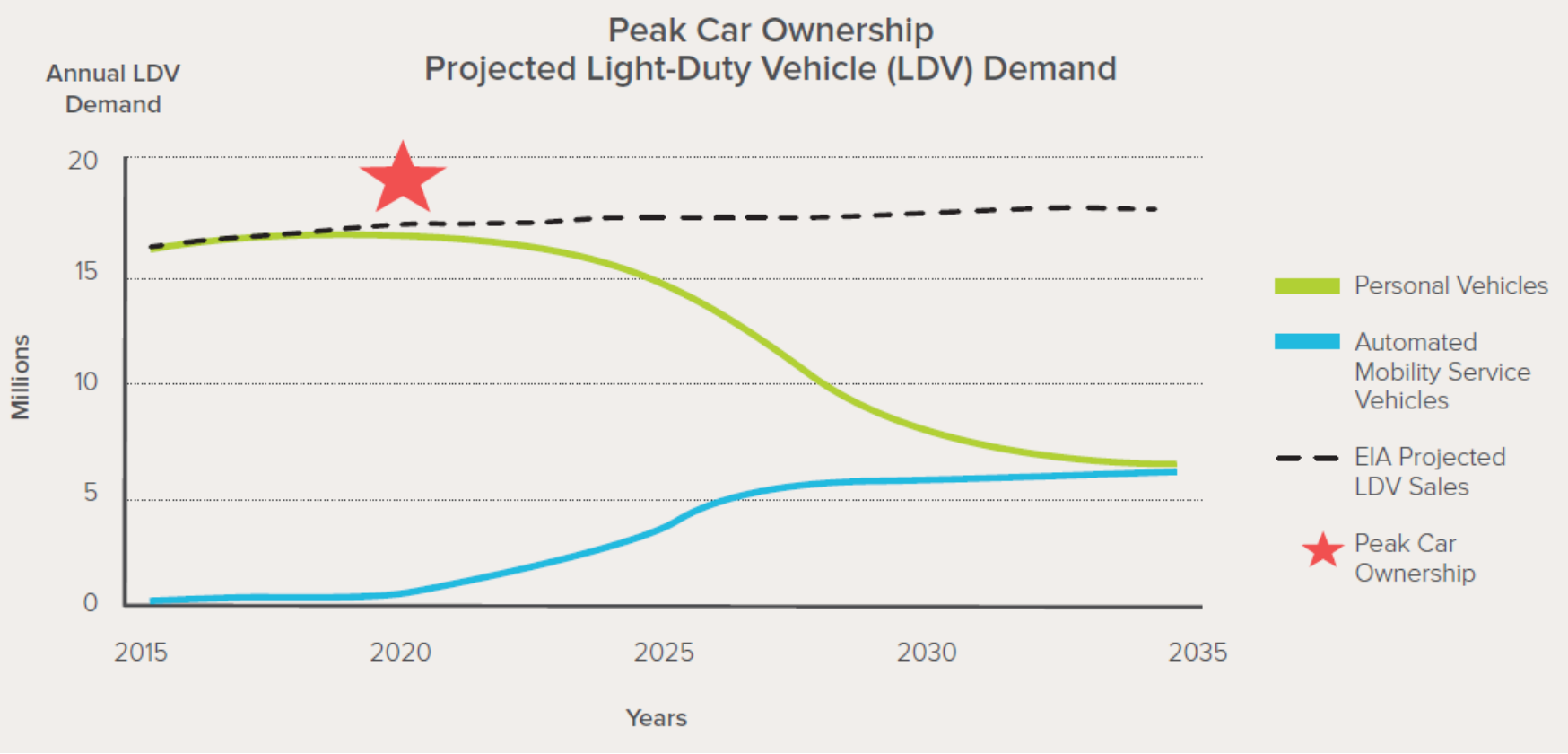


Source: (Ward's Automotive, 2016)

Source: http://www.cargroup.org/?module=Publications&event=View&pubID=145

LDV market

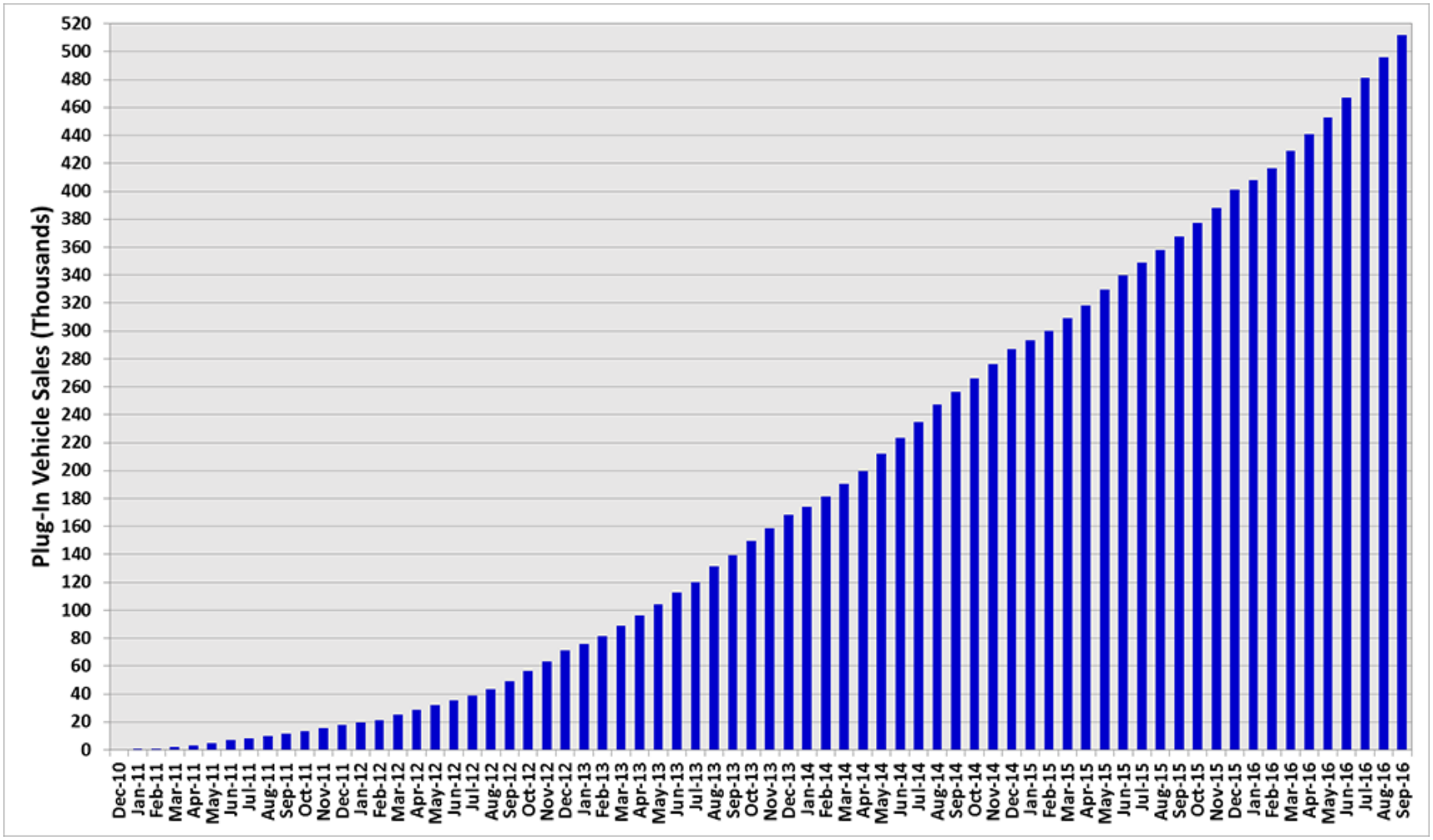
RMI: Cheap access to automated mobility service vehicles can lead to rapid decline in car sales in next decade



Source: http://www.rmi.org/peak_car_ownership

EV market

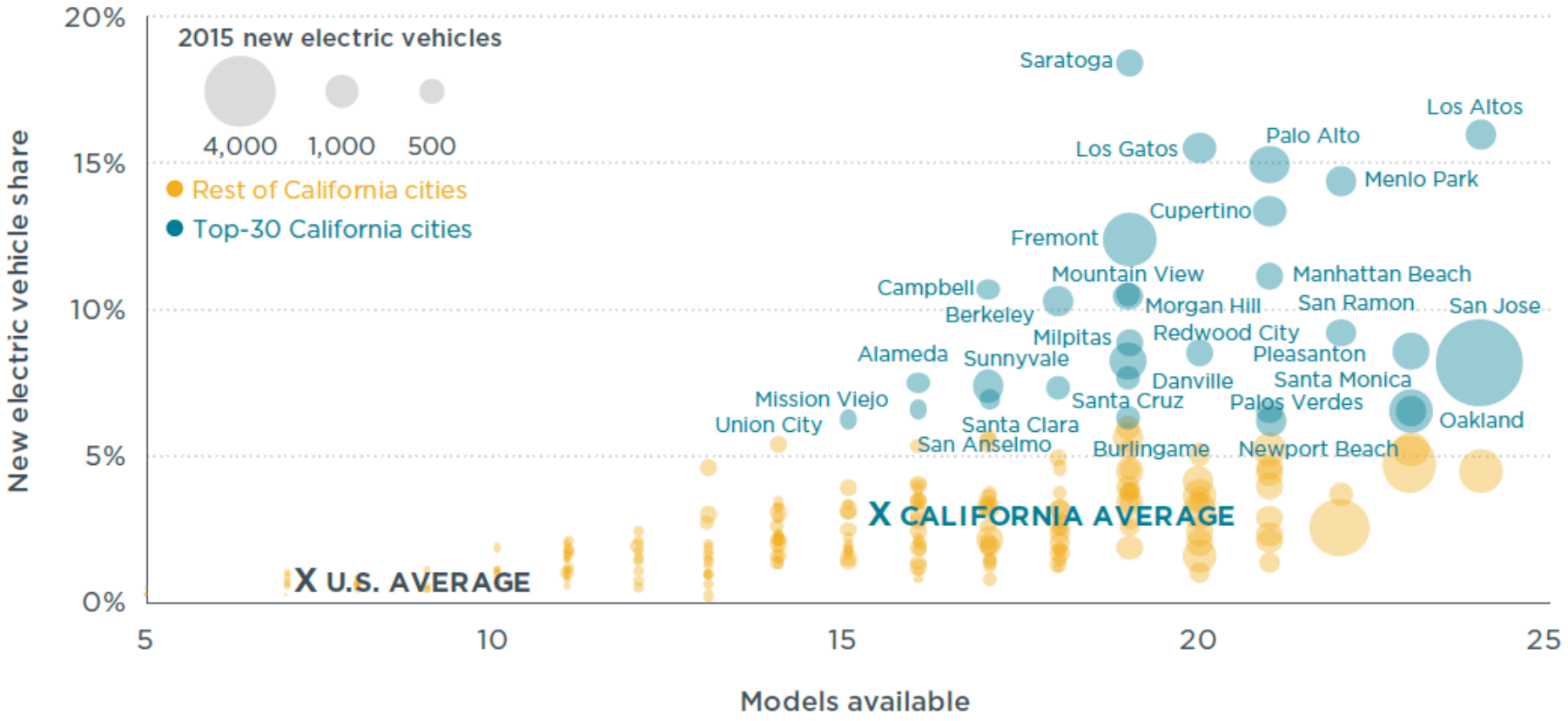
FOTW: Over 500,000 EVs have been sold in the United States since 2010



Source: http://energy.gov/eere/vehicles/fact-947-october-17-2016-over-half-million-plug-vehicles-have-been-sold-united-states

EV market

ICCT: EV sales in California correlated with number of vehicle models available



Source: http://www.theicct.org/ev-markets-calif-cities-sept2016

EV market

ICCT: EV sales correlated with state and local incentives

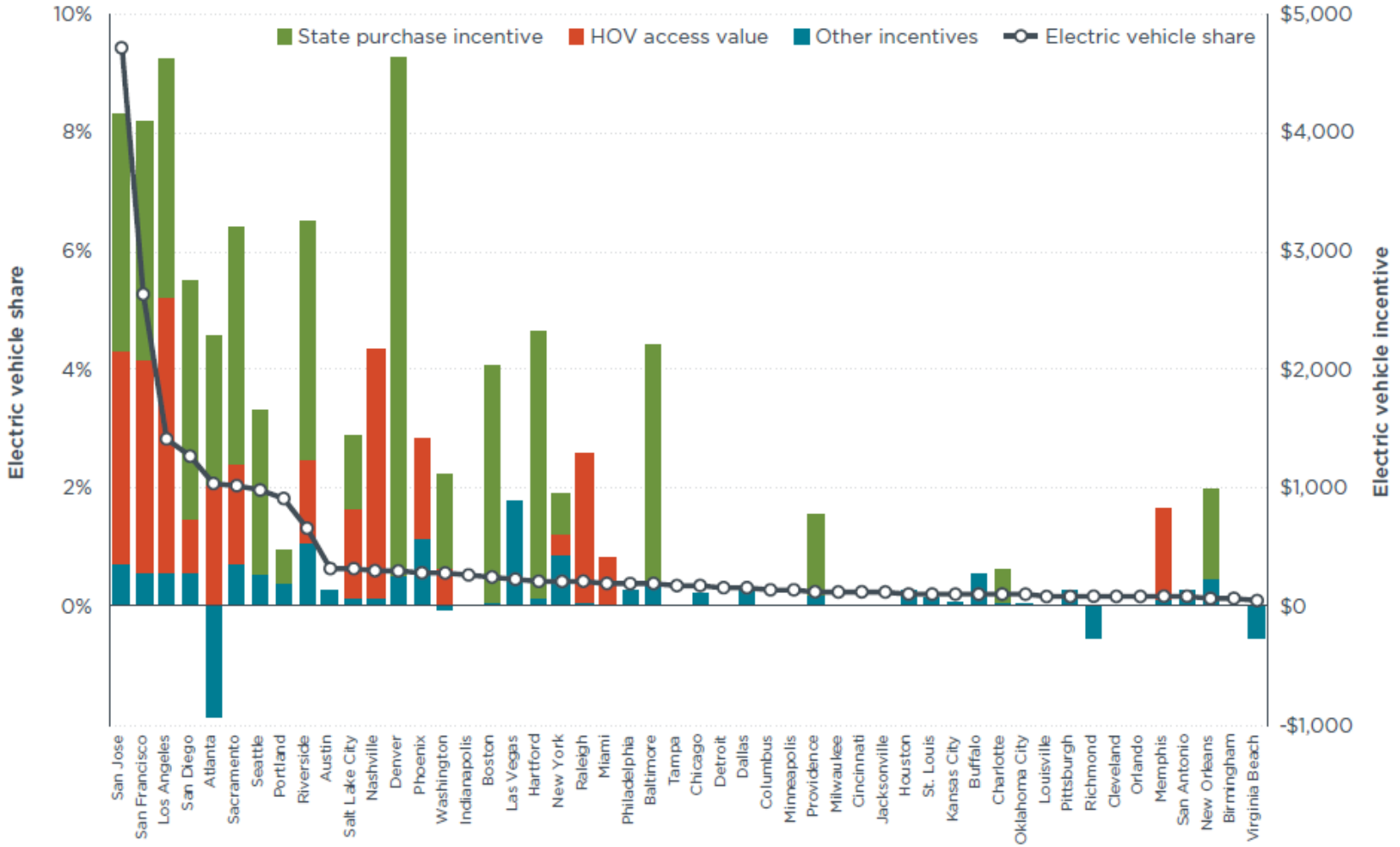
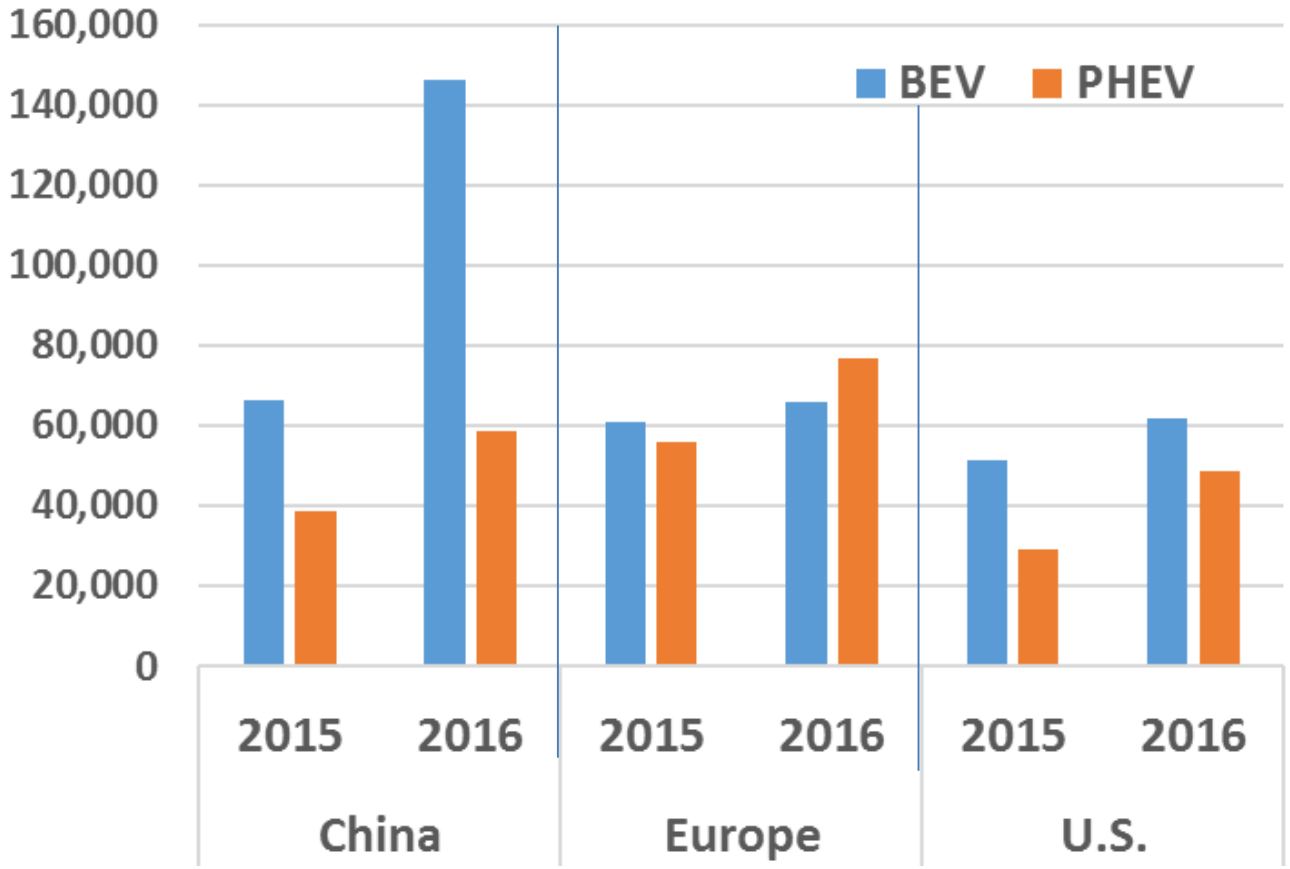


Figure 5. Electric vehicle share of new vehicles and available consumer incentives

Source: http://www.theicct.org/ev-markets-calif-cities-sept2016

EV market

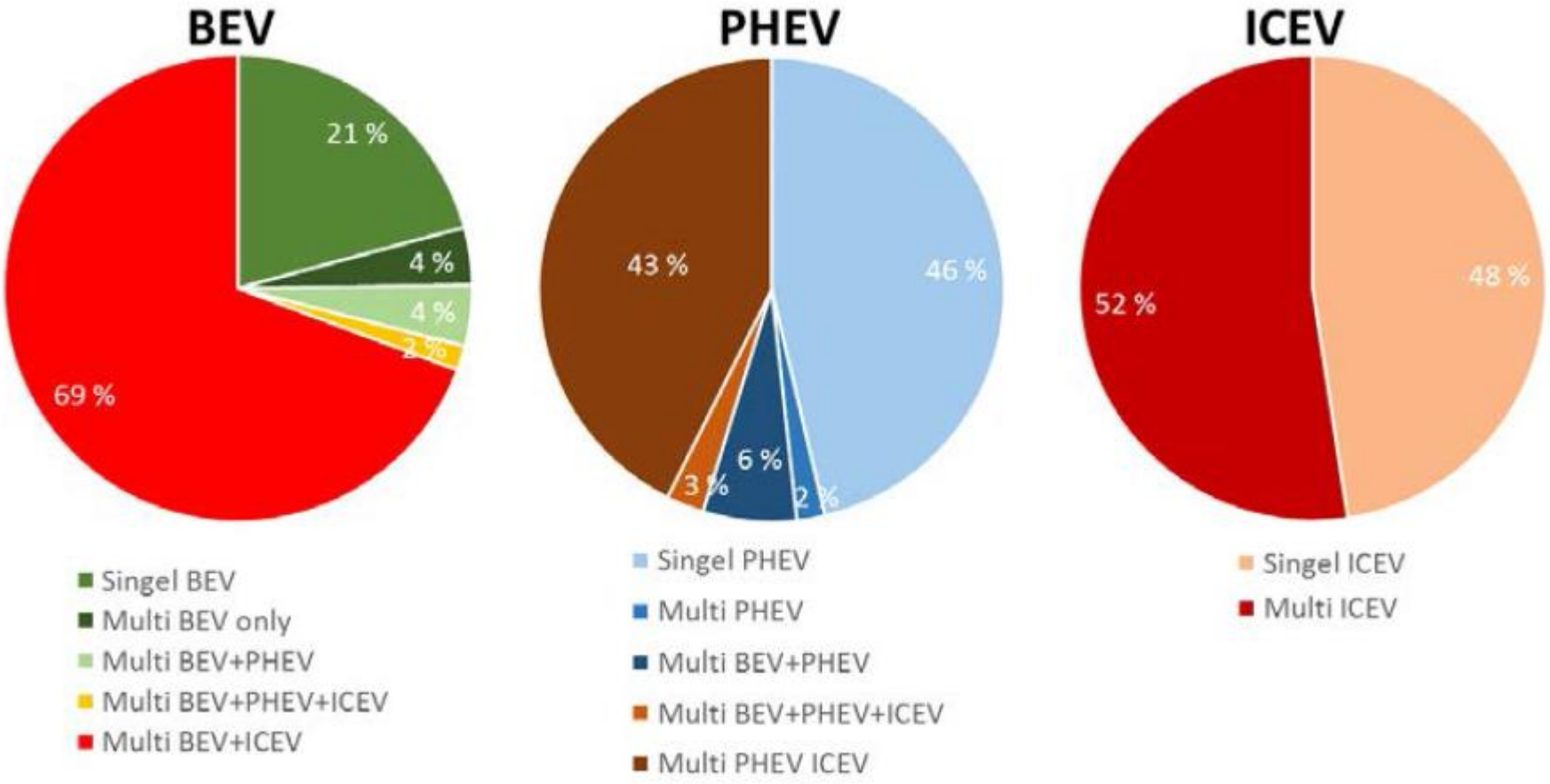
ANL: Through October 2016, BEV and PHEV sales up in each of three largest markets over 2015



Source: Y. Zhou, Argonne National Laboratory

EV market

TØI: BEVs in Norway (world's largest EV market by %) often in multi-vehicle households, PHEV similar to ICEV



Source: https://www.toi.no/getfile.php?mmfileid=43161

topics

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automotive markets

3 technologies studies

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outline

3 technologies studies

vehicle technologies

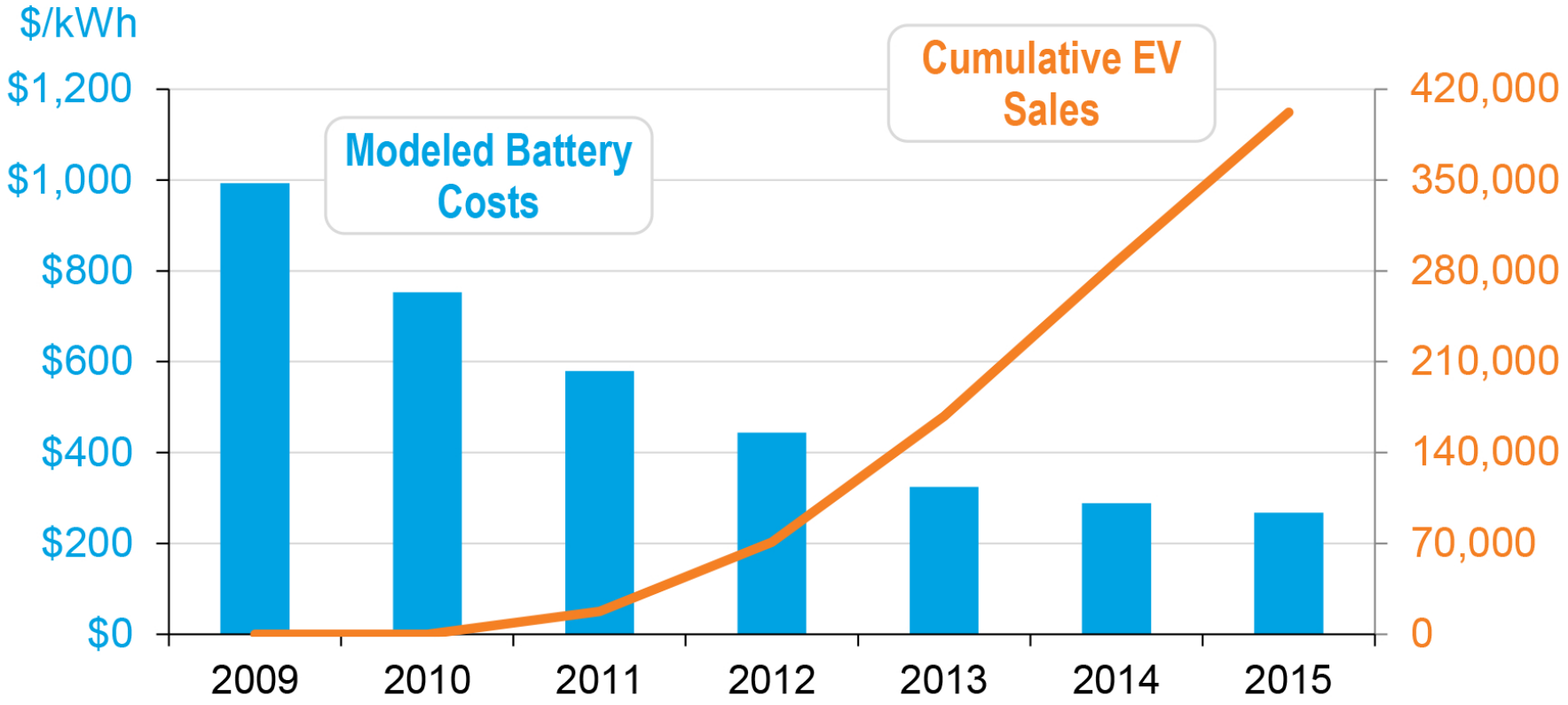
> DOE: Battery prices continue to drop
> EPA: Adjusted fuel economy at all-time high for LDV
> ICCT: Fuel-efficient technologies are being used in US and EU

CAVs

> ANL/NREL/ORNL/DOE: Fuel efficiency may be increased by CAVs technologies; high uncertainty in fuel consumption
> ORNL: CAVs can lower fuel consumption at intersections

battery prices

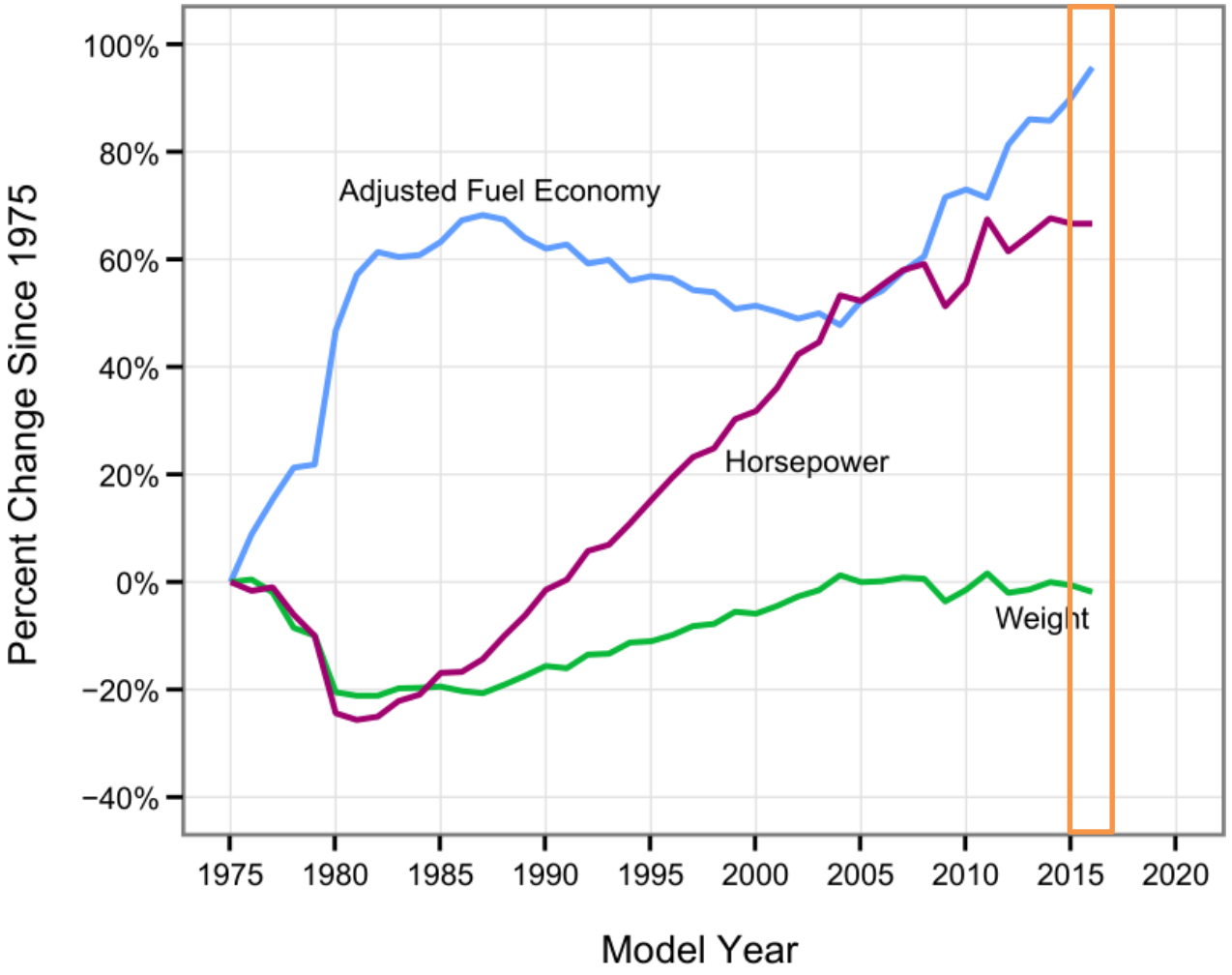
DOE: Electric vehicle battery prices have dropped fourfold in 7 years while electric vehicle sales grew



Source: http://energy.gov/eere/downloads/revolutionnow-2016-update

fuel economy

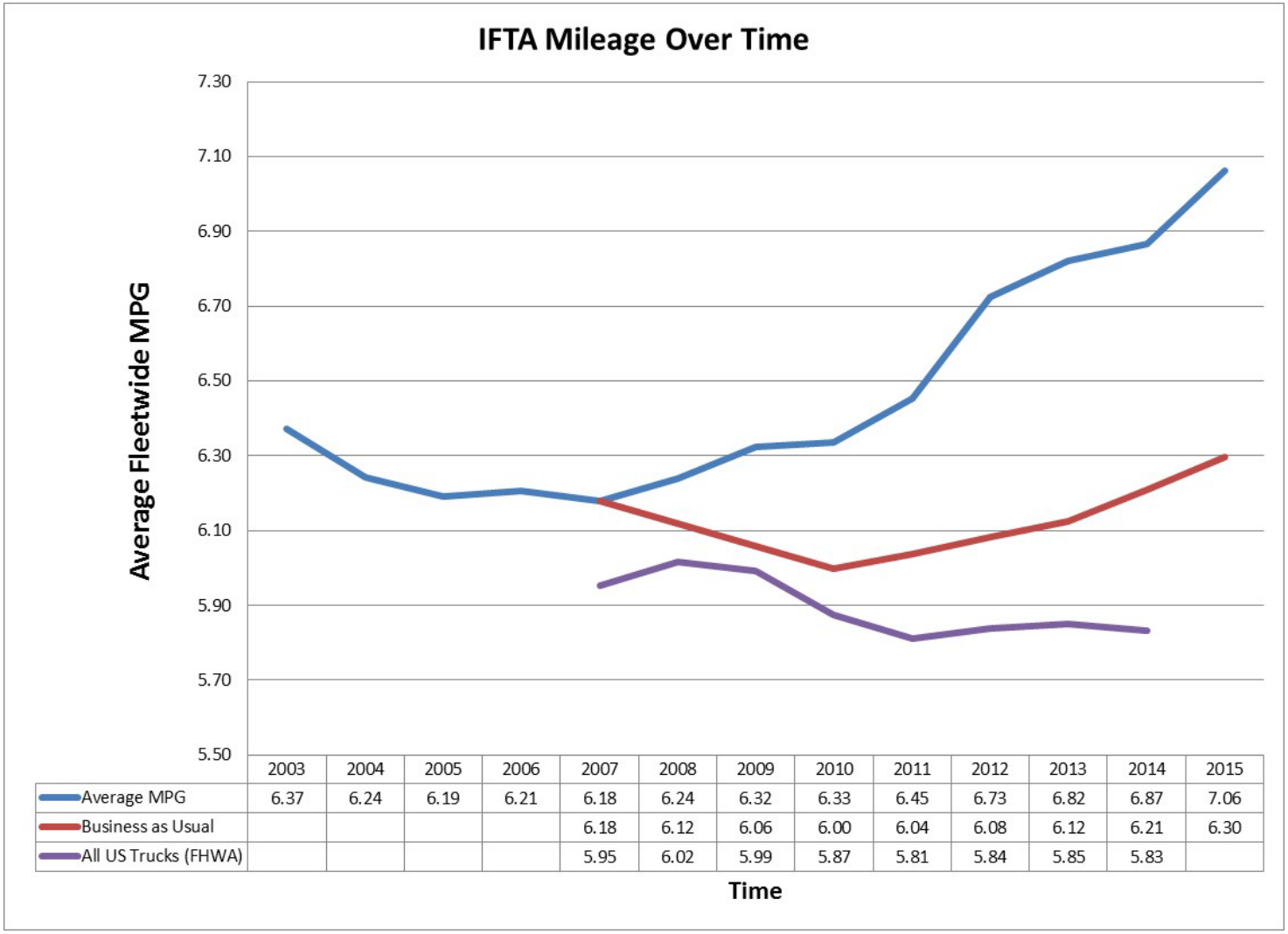
EPA: Adjusted fuel economy hit all time high in MY2016, while horsepower and weight stayed steady



Source: https://www.epa.gov/fuel-economy/download-co2-and-fuel-economy-trends-report-1975-2016

heavy trucks

NACFE: Truck fuel economy continues to improve

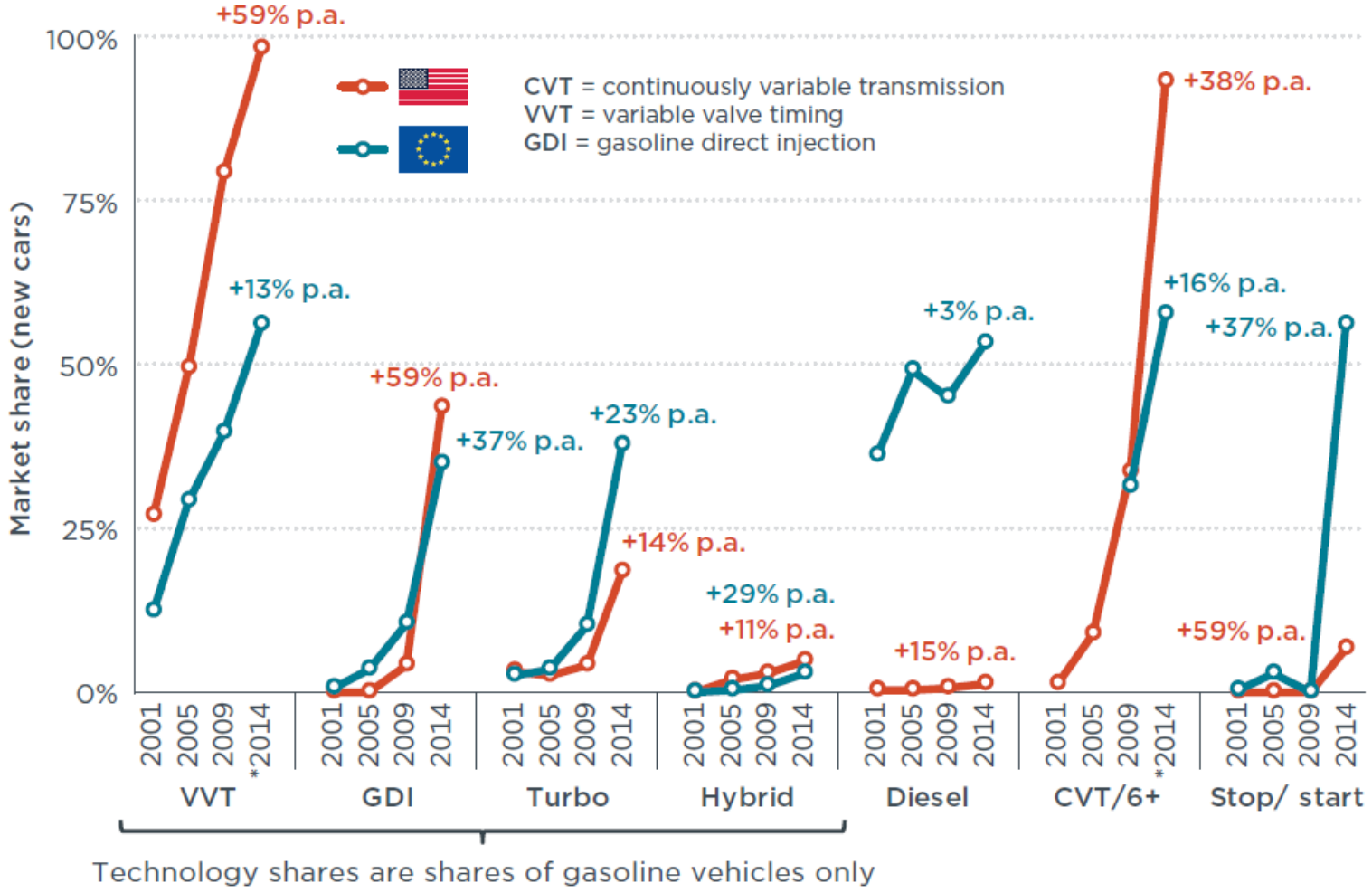


	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Average MPG	6.37	6.24	6.19	6.21	6.18	6.24	6.32	6.33	6.45	6.73	6.82	6.87	7.06
Business as Usual					6.18	6.12	6.06	6.00	6.04	6.08	6.12	6.21	6.30
All US Trucks (FHWA)					5.95	6.02	5.99	5.87	5.81	5.84	5.85	5.83	

Source: http://www.truckingefficiency.org/annual-fleet-fuel-studies

technology uptake

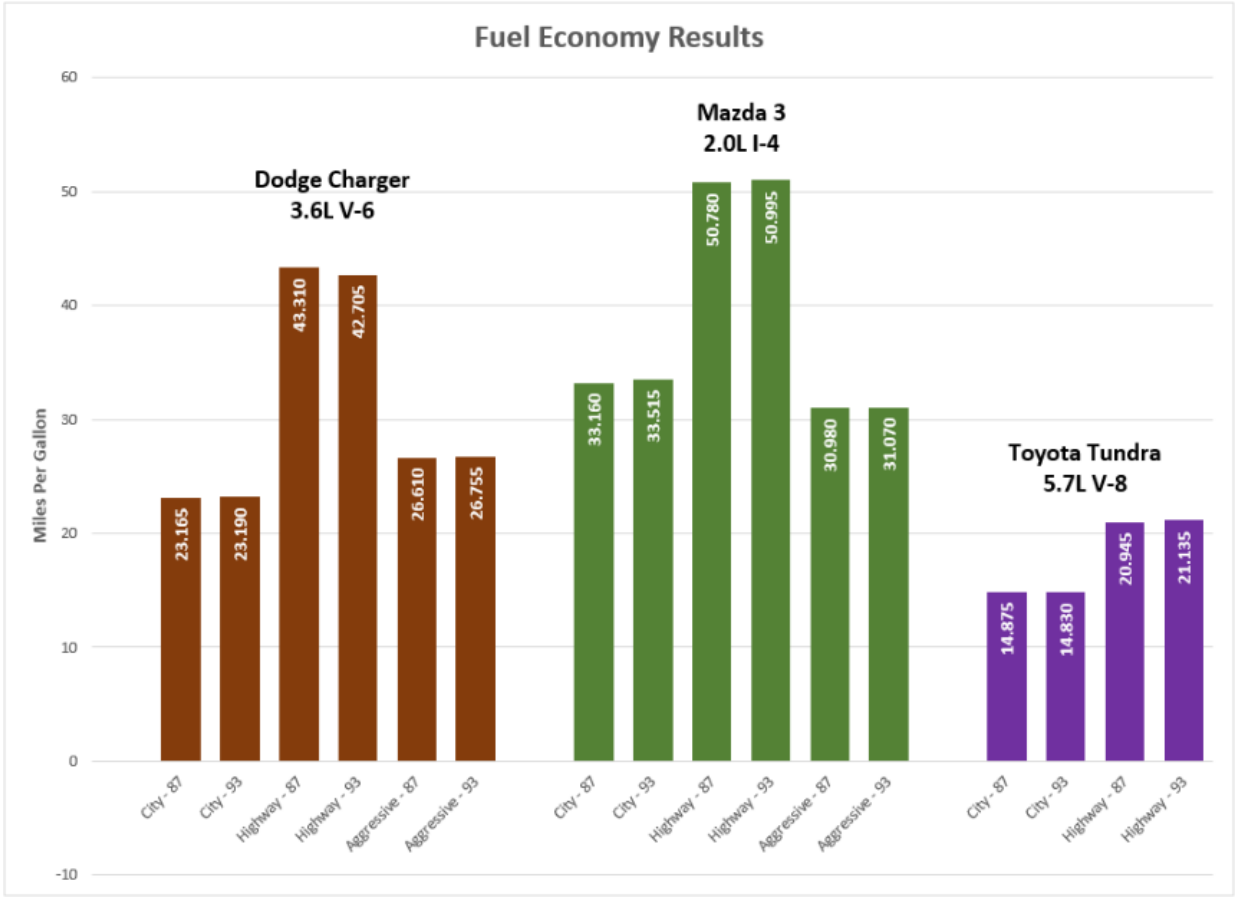
ICCT: Fuel economy-improving technologies are growing in both Europe and the United States



Source: http://www.theicct.org/EU-and-US-PV-technology-deployment

gasoline octane

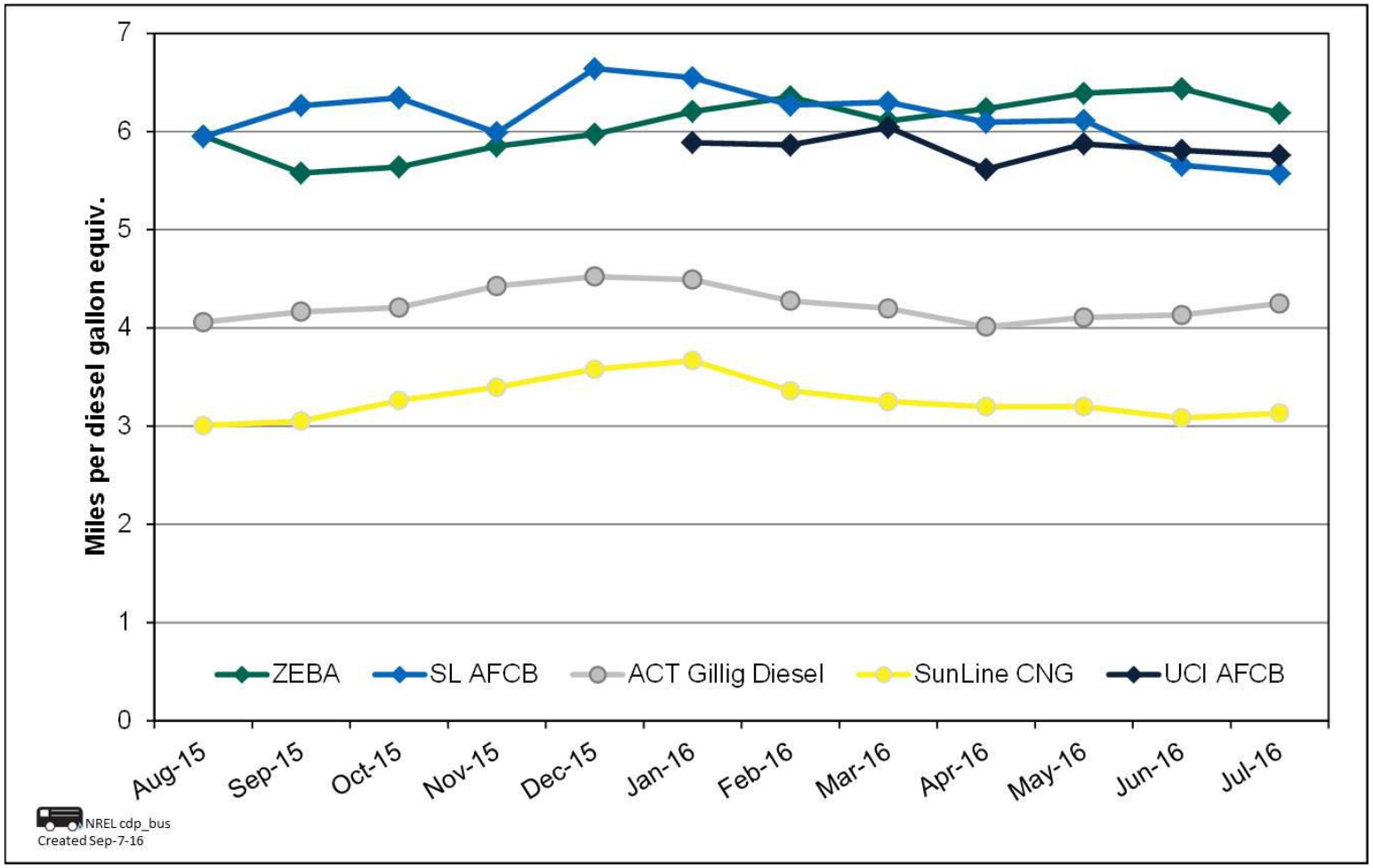
AAA: Engines designed for regular gasoline show negligible benefits with premium gasoline; U.S. drivers waste $2 billion/year on premium gasoline



Source: http://publicaffairsresources.aaa.biz/wp-content/uploads/2016/08/Premium-Fuel-REPORT-FINAL3.pdf

fuel economy

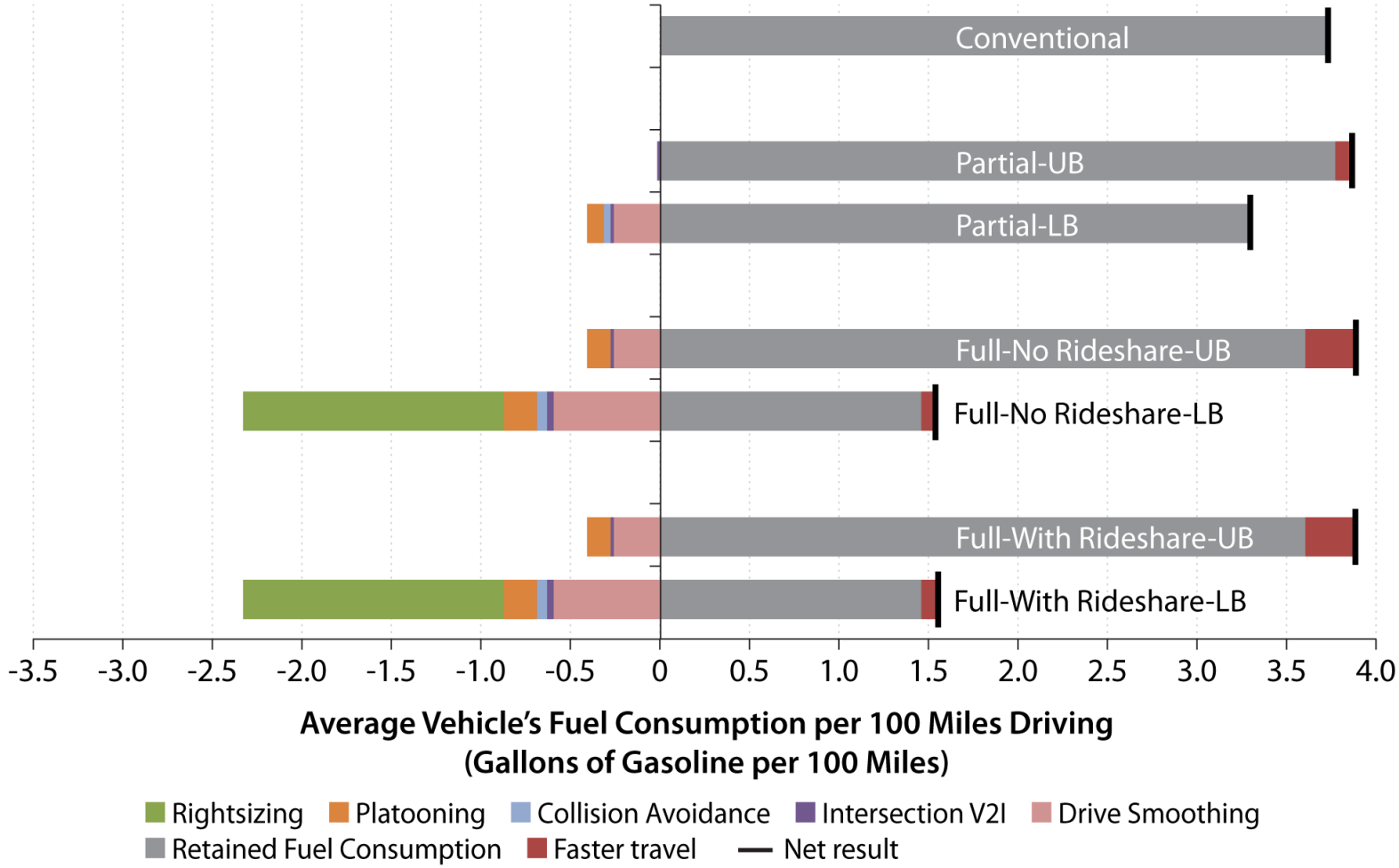
NREL: Fuel-cell buses seen with higher on-road fuel economy than diesel buses, CNG behind



Source: http://www.energy.gov/eere/fuelcells/downloads/fuel-cell-buses-us-transit-fleets-current-status-2016

CAVs

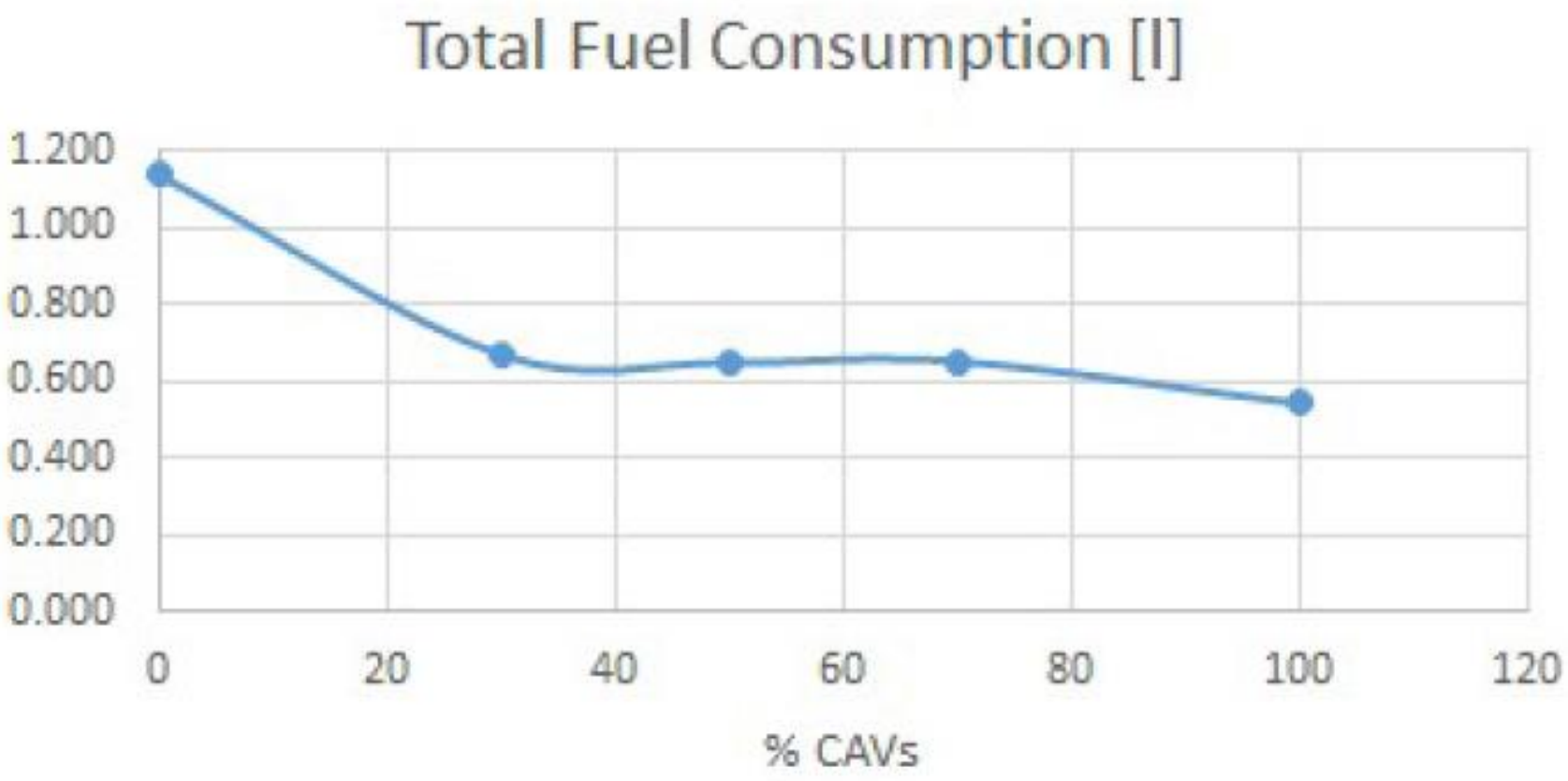
ANL/NREL/ORNL/DOE: Fuel consumption per mile potentially much lower in CAVs vehicles



Source: http://www.nrel.gov/docs/fy17osti/67216.pdf

CAVs

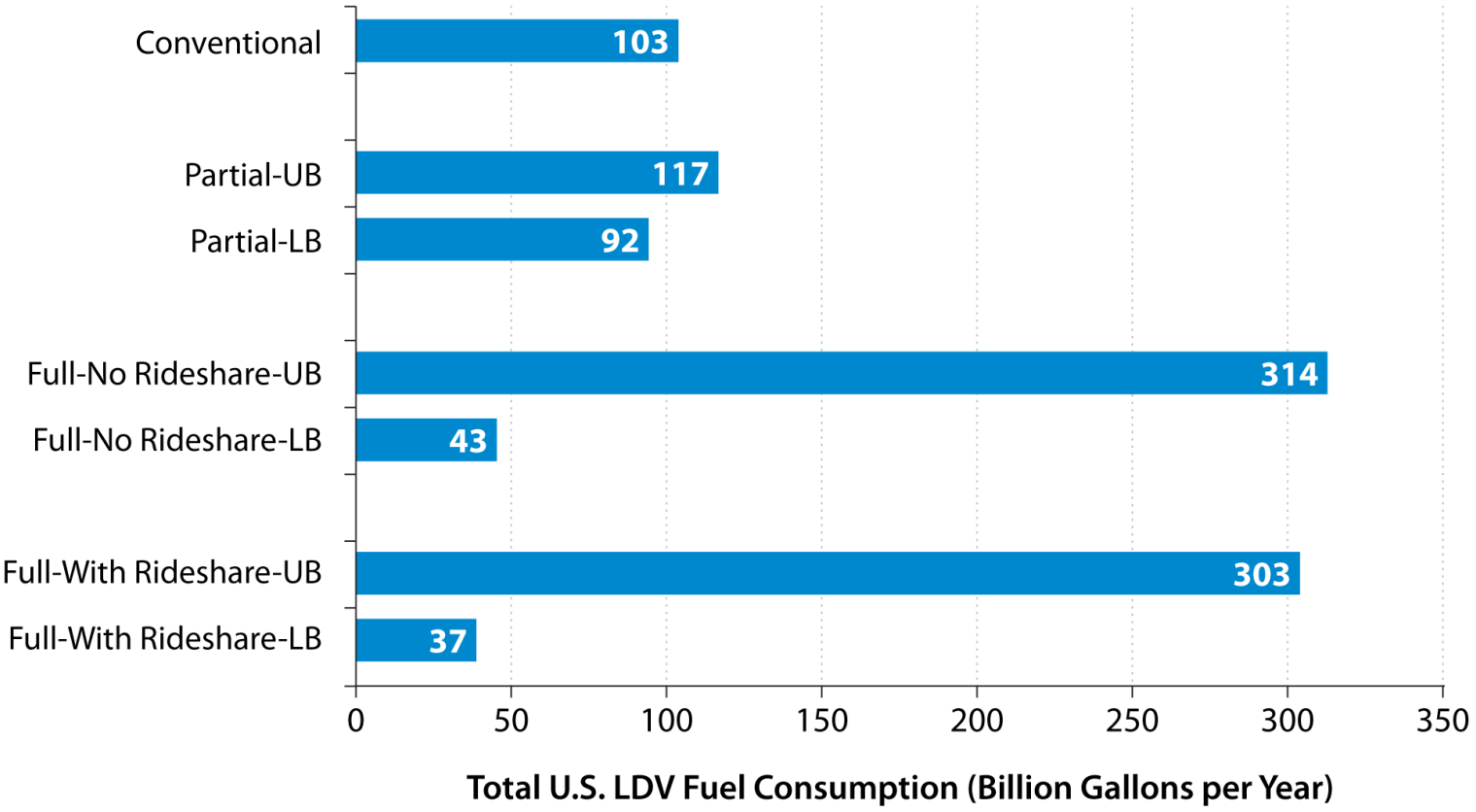
ORNL: Modest penetrations of CAVs technology can lead to fuel economy improvements at intersections



Source: http://dl.acm.org/citation.cfm?doid=3003965.3003969

CAVs

ANL/NREL/ORNL/DOE: Broad range of fuel use bounds in connected in automated vehicles due to uncertainty in fuel economy and travel demand



Source: http://www.nrel.gov/docs/fy17osti/67216.pdf

topics

energy markets

automotive markets

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4 environmental studies

consumers & opinion surveys

policy & business studies

qar

outline

4 environmental studies

emissions

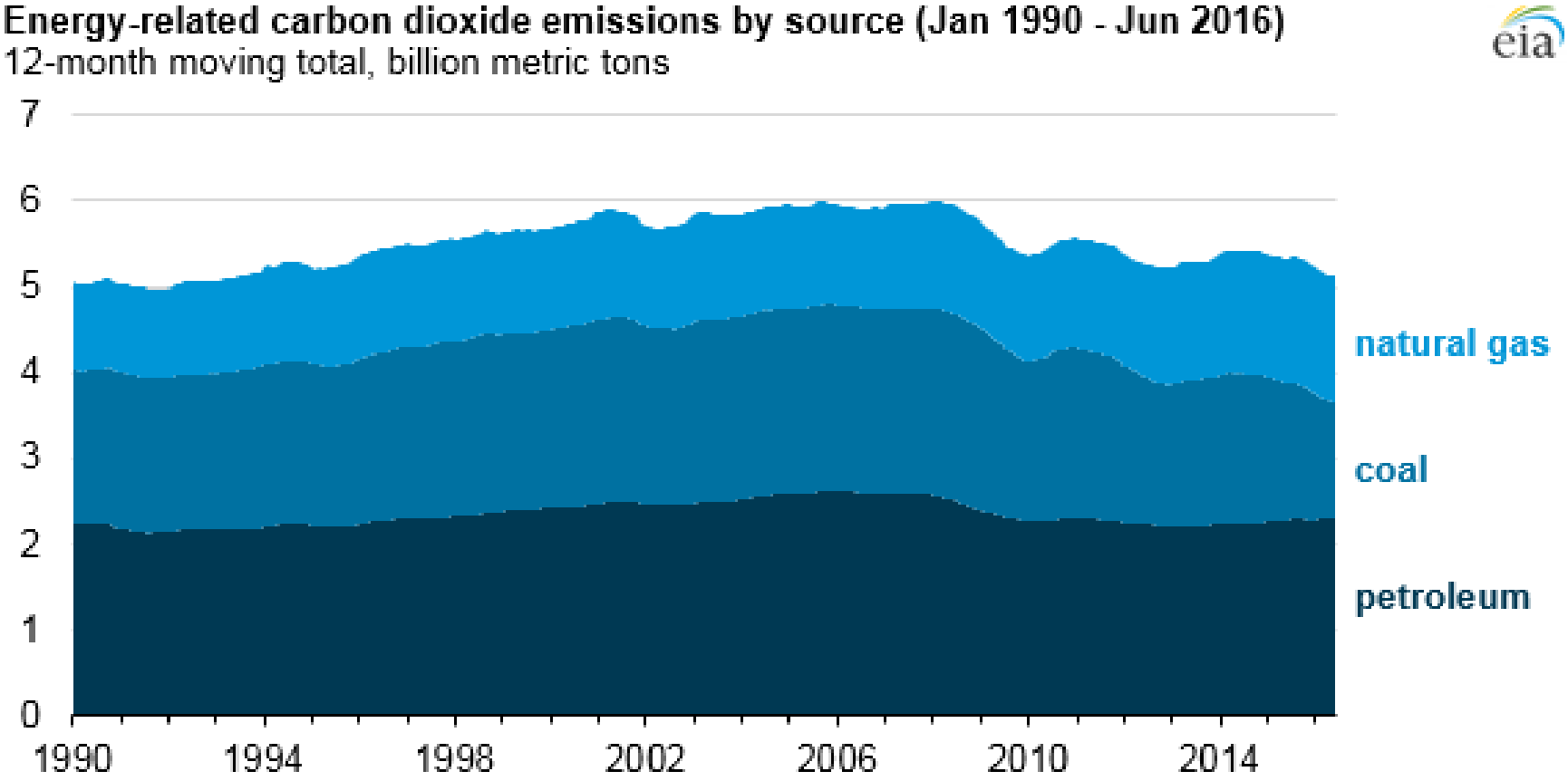
- EIA: U.S. CO_2 emissions at lowest level in 25 years
- UEA: Worldwide CO_2 emissions nearly flat for last three years
- FOTW/MIT: EVs tend to have lower emissions than ICEVs

public health

- ALA: Reduced air pollution can improve public health and mitigate climate costs

emissions

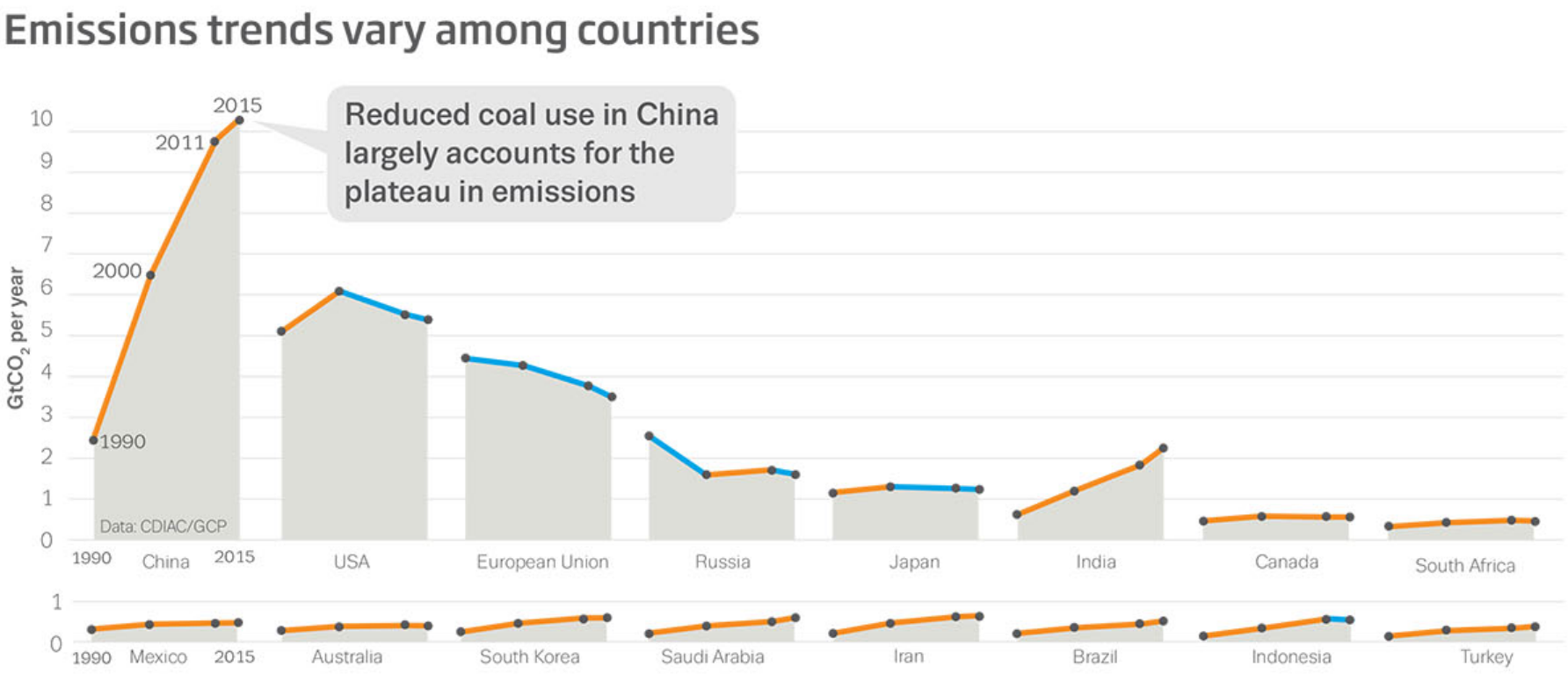
EIA: U.S. CO_2 emissions at lowest level in 25 years



Source: http://www.eia.gov/todayinenergy/detail.php?id=28312

emissions

UEA: Worldwide CO_2 emissions nearly flat for three consecutive years; large variations between countries

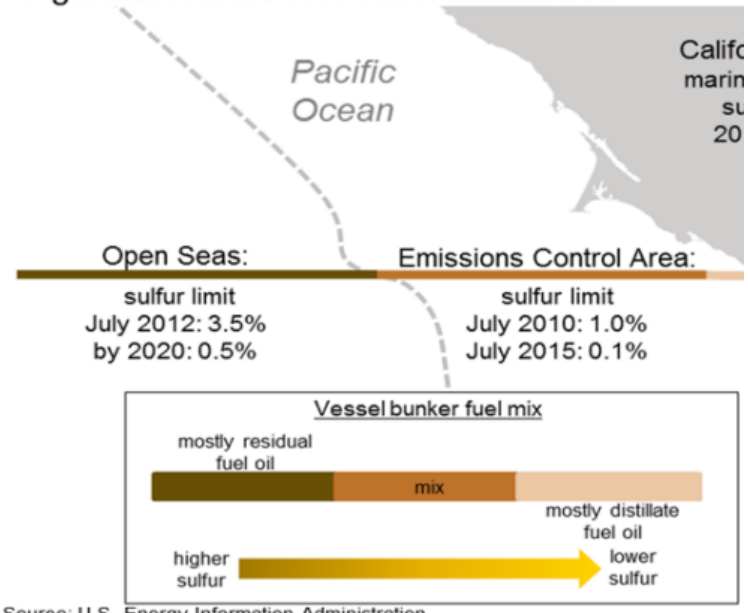


Source: https://www.uea.ac.uk/about/-/low-growth-in-global-carbon-emissions-continues-for-third-successive-year

emissions

EIA: International Maritime Organization agreeing to lower sulfur content in fuel in international waters

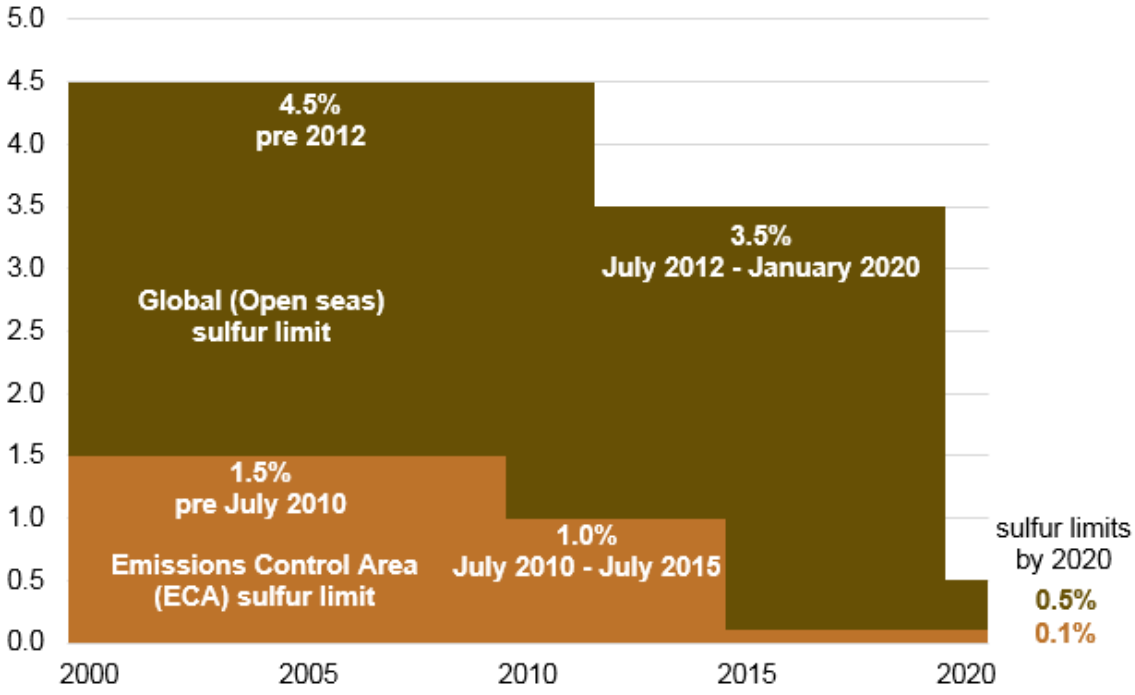
Figure 2. Marine fuel sulfur limit zones



Source: U.S. Energy Information Administration

Figure 1. Marine fuel sulfur limits

percent by weight

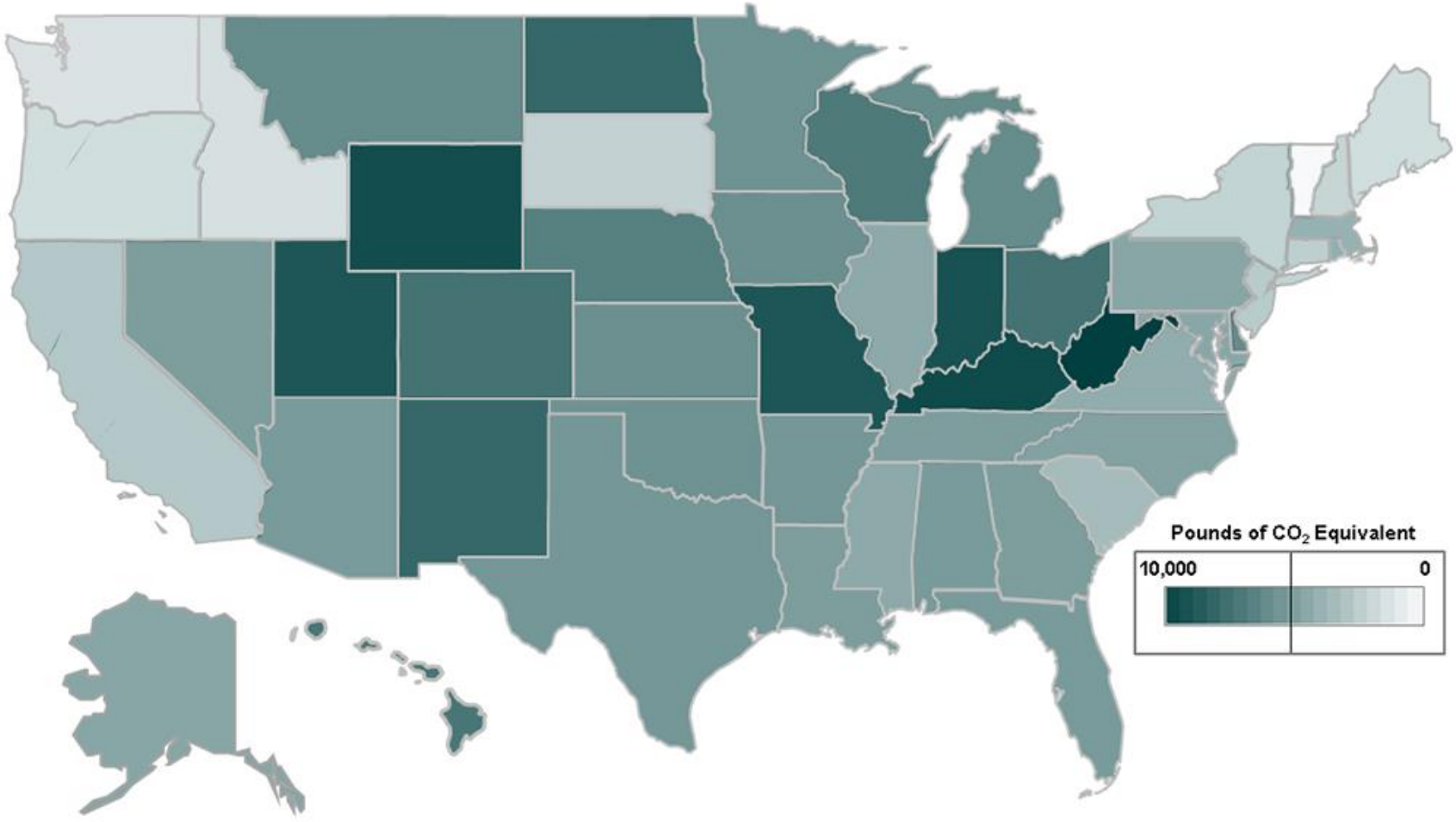


Source: U.S. Energy Information Administration

Source: http://www.eia.gov/petroleum/weekly/archive/2016/161123/includes/analysis_print.cfm

emissions

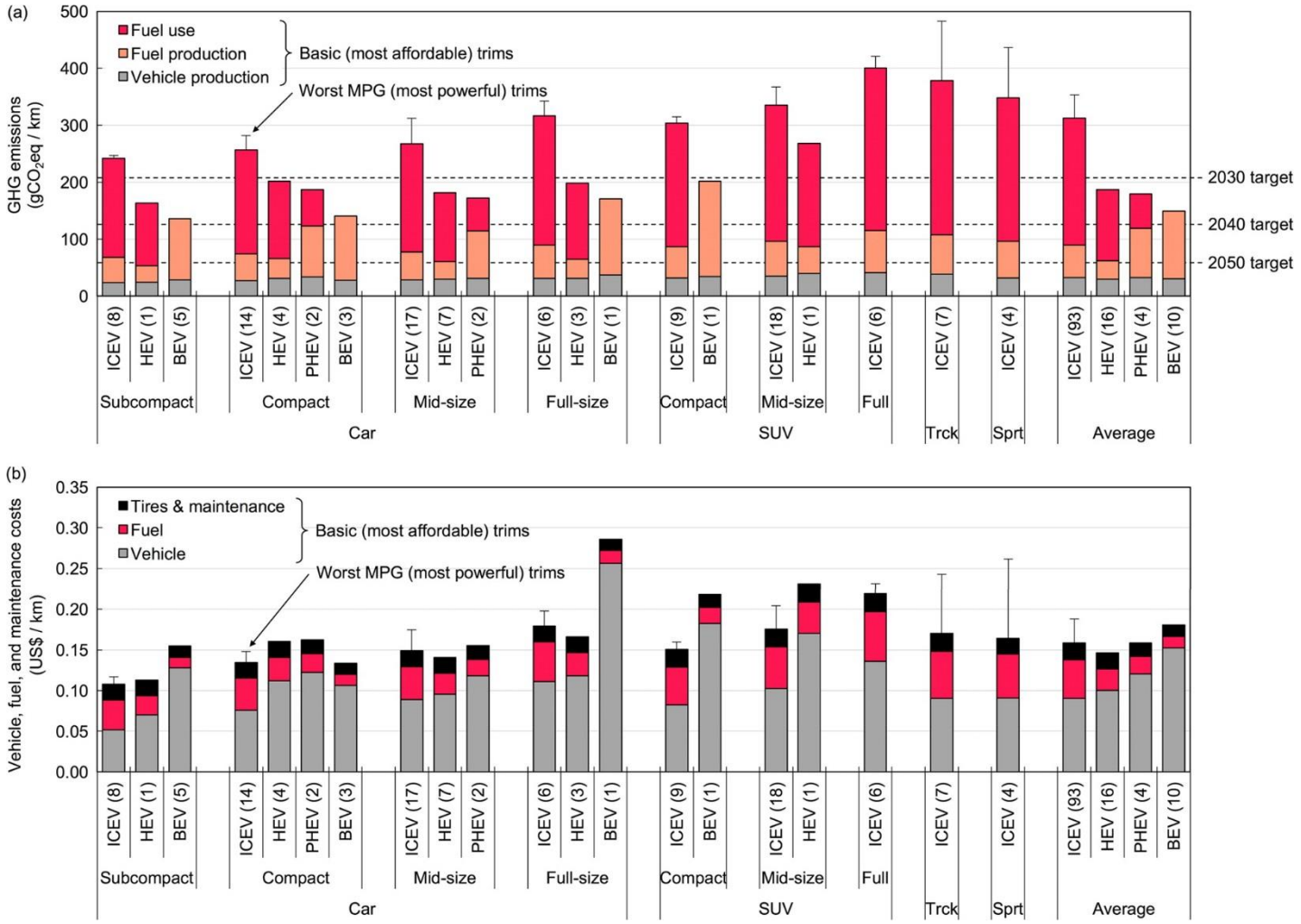
FOTW: Well-to-wheels emissions for EV vary by state, lower than emissions from CAFE-average ICE



Source: http://energy.gov/eere/vehicles/fact-950-november-7-2016-well-wheel-emissions-typical-ev-state-2015

emissions

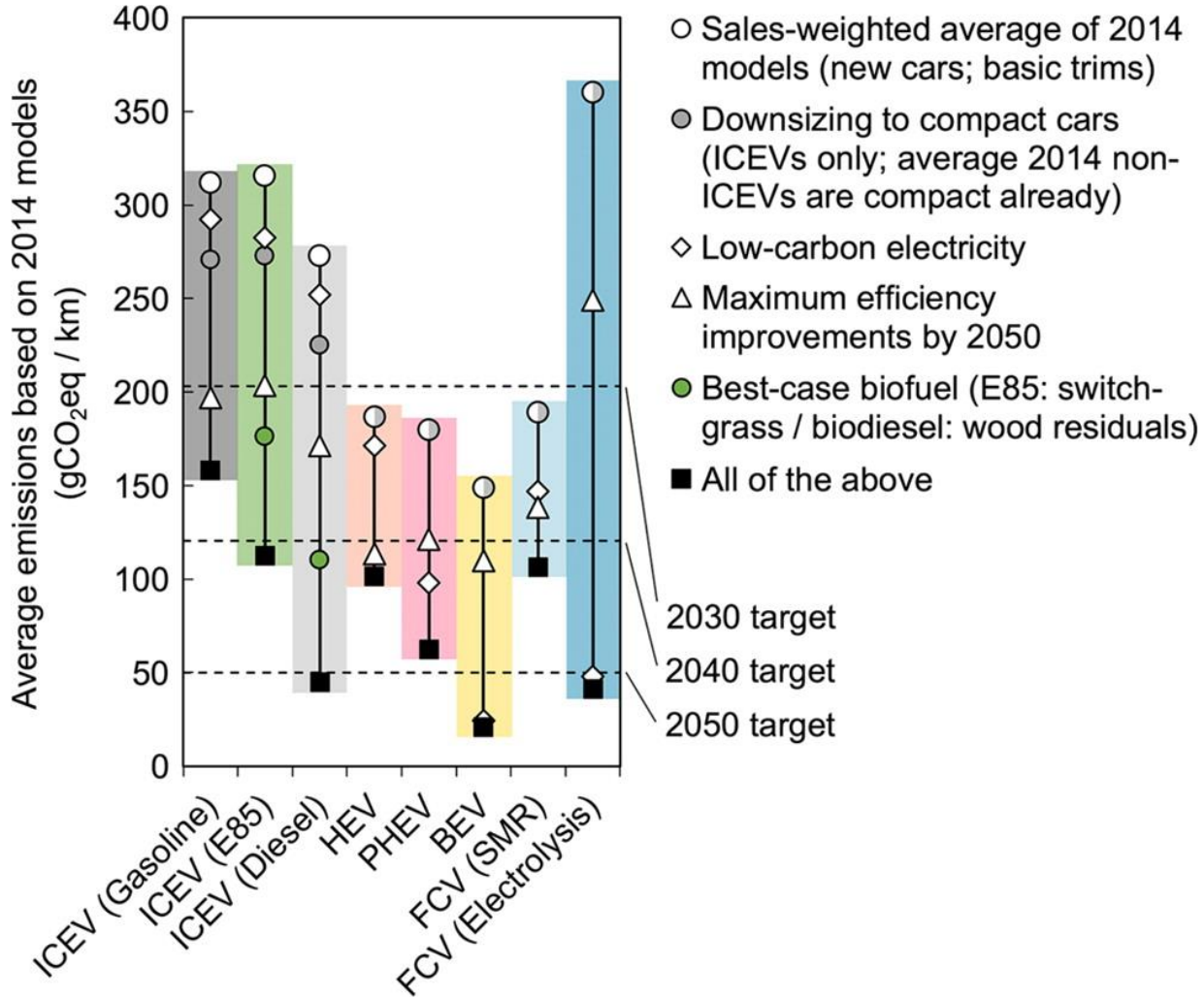
MIT: BEV and HEV have lower emissions than ICE in each size class, typically higher cost as well



Source: http://pubs.acs.org/doi/full/10.1021/acs.est.6b00177#

emissions

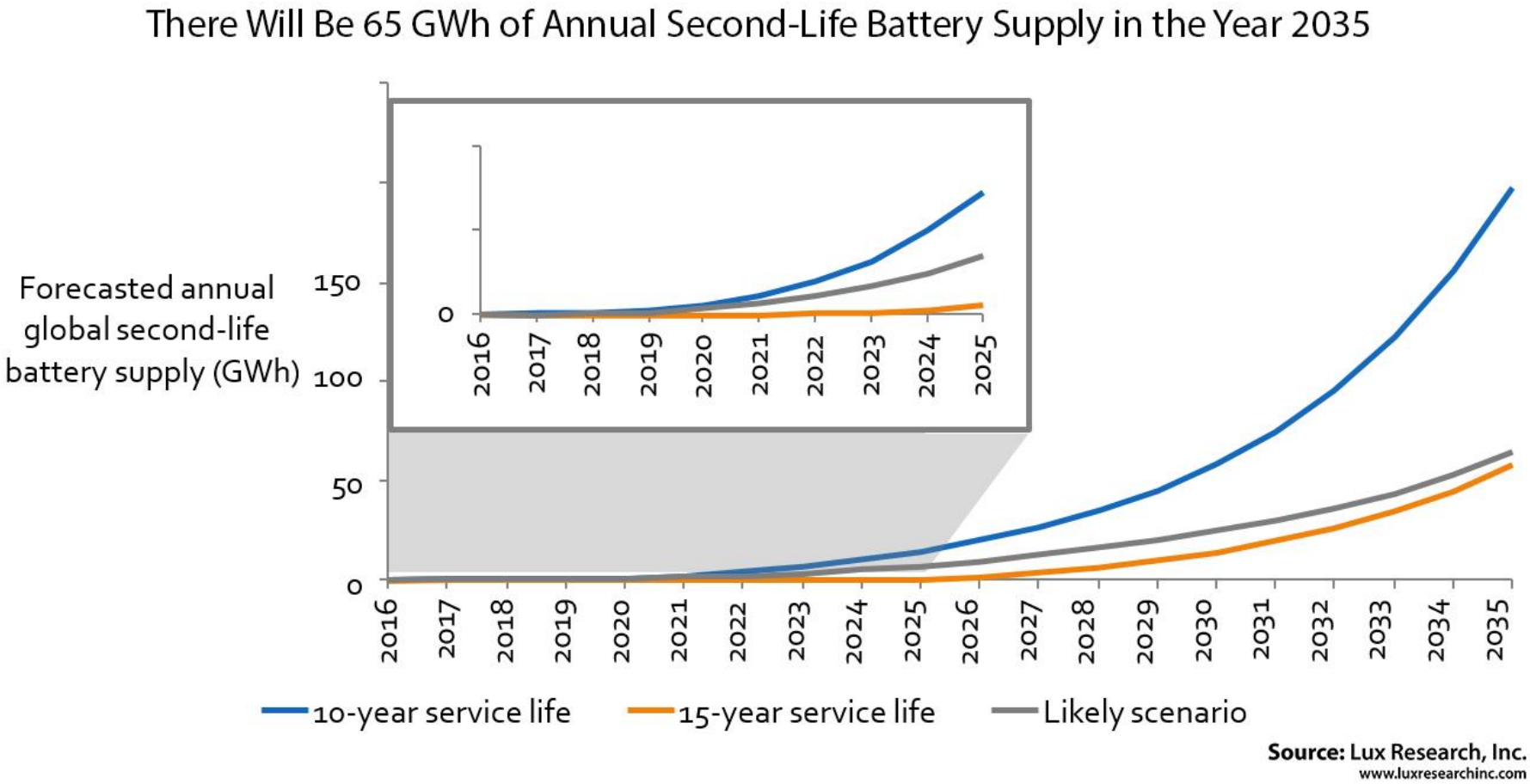
MIT: Emissions will decrease by improving both vehicles and fuels



Source: http://pubs.acs.org/doi/full/10.1021/acs.est.6b00177#

battery recycling

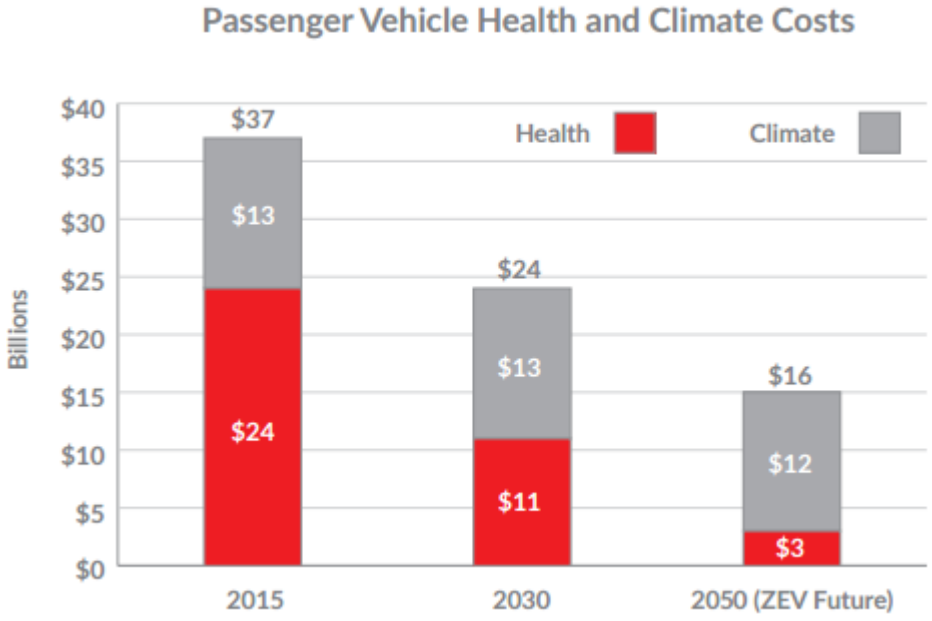
Lux: Second-life battery supply will grow as EVs age, but recycling may be more economical

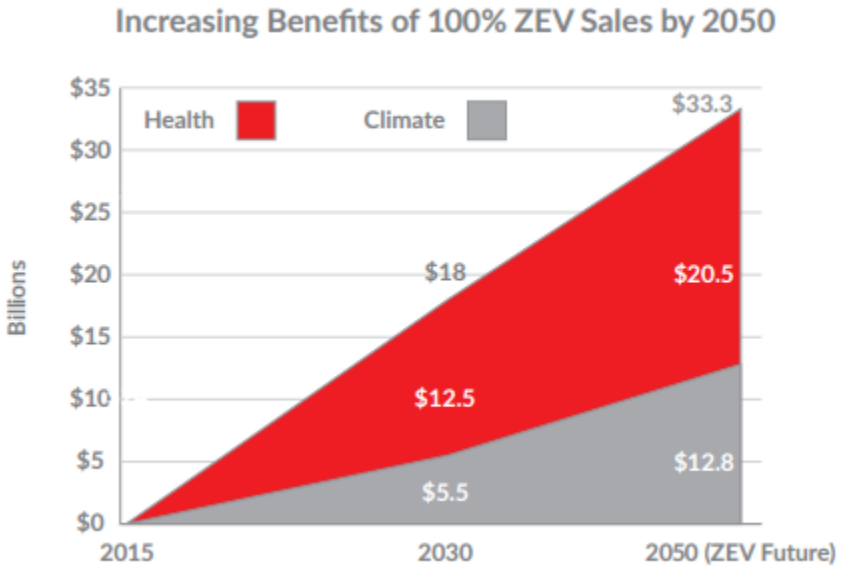


Source: http://www.marketwired.com/press-release/recycling-not-reuse-is-better-choice-batteries-from-retired-electric-vehicles-2177752.htm

public health

ALA: ZEVs can save over $30 billion in health and climate costs in the United States





Source: https://electrek.co/2016/10/27/an-all-electric-car-fleet-can-save-lives-and-over-30-billions-in-health-climate-costs-in-the-us-says-study/

topics

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5 consumers & opinion surveys

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outline

5 consumer & opinion surveys

travel behavior

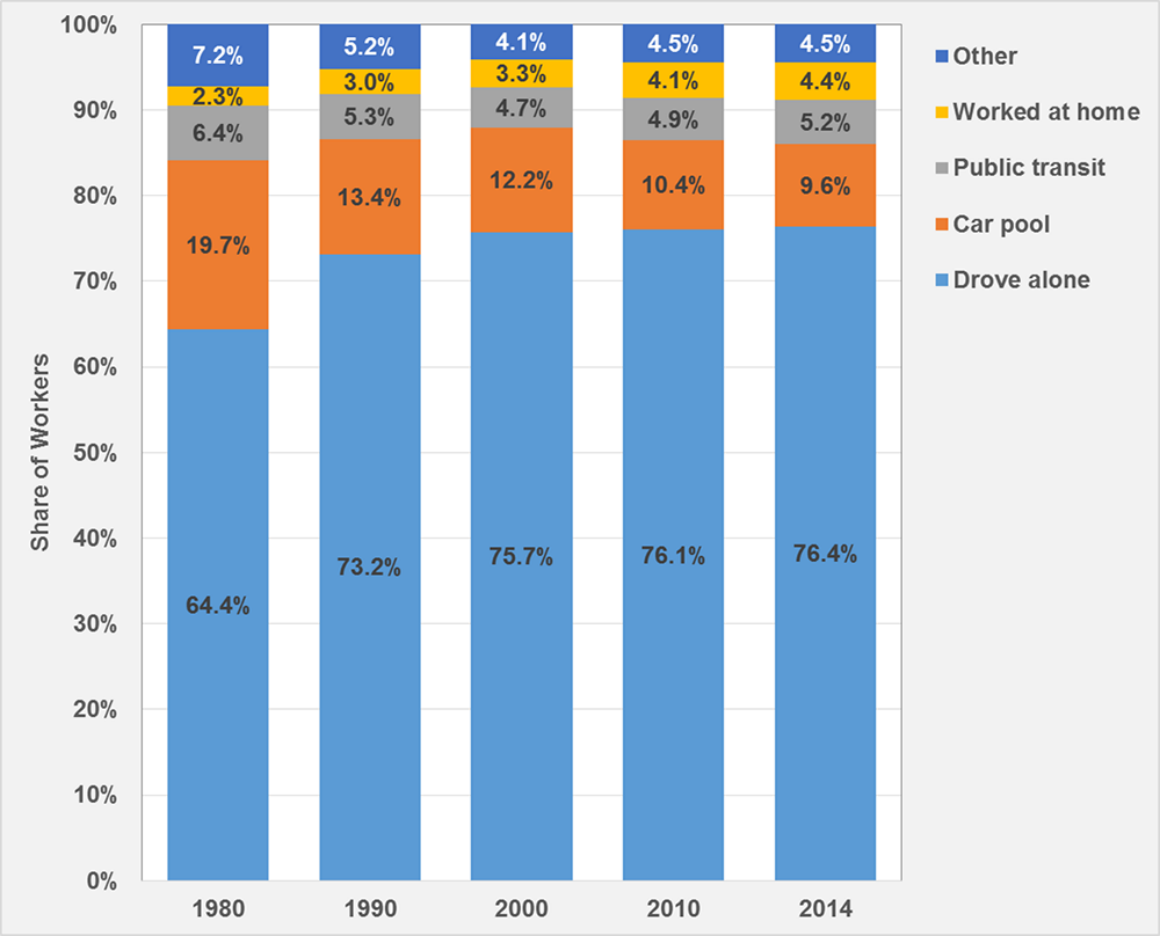
> FOTW: Driving alone to work most common method of commute

consumer sentiments

> FOTW/NREL: Electricity viewed favorably as replacement fuel
> KBB: Price and software concerns on consumer minds for CAVs
> KBB: Likely CAVs-adopters are younger and more digitally savvy
> McKinsey: Most consumers prefer lowest cost shipping options

driver behavior

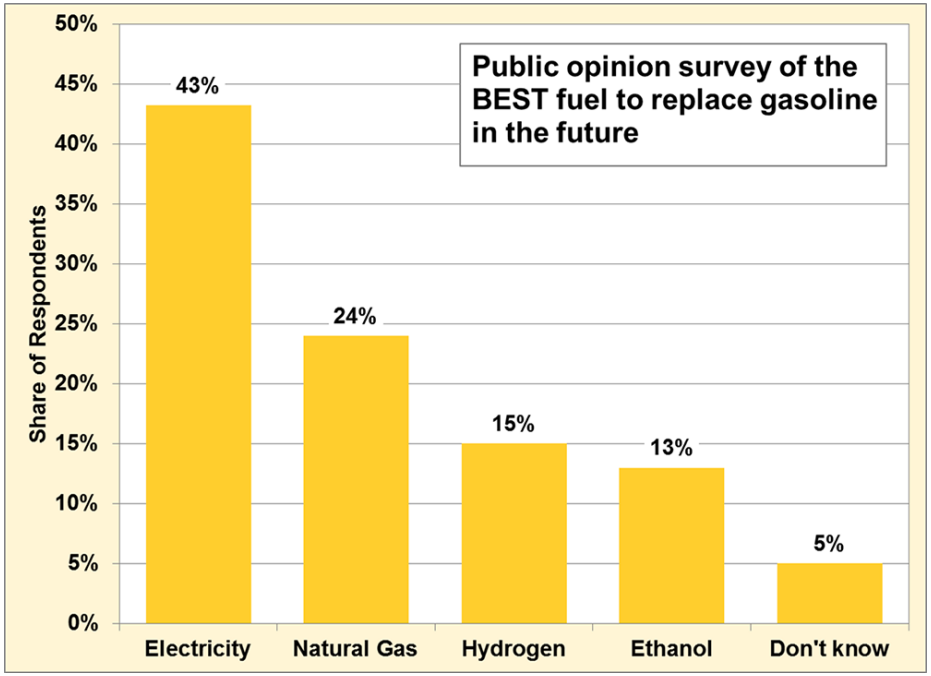
FOTW: Driving alone is most common means of commuting to work in United States

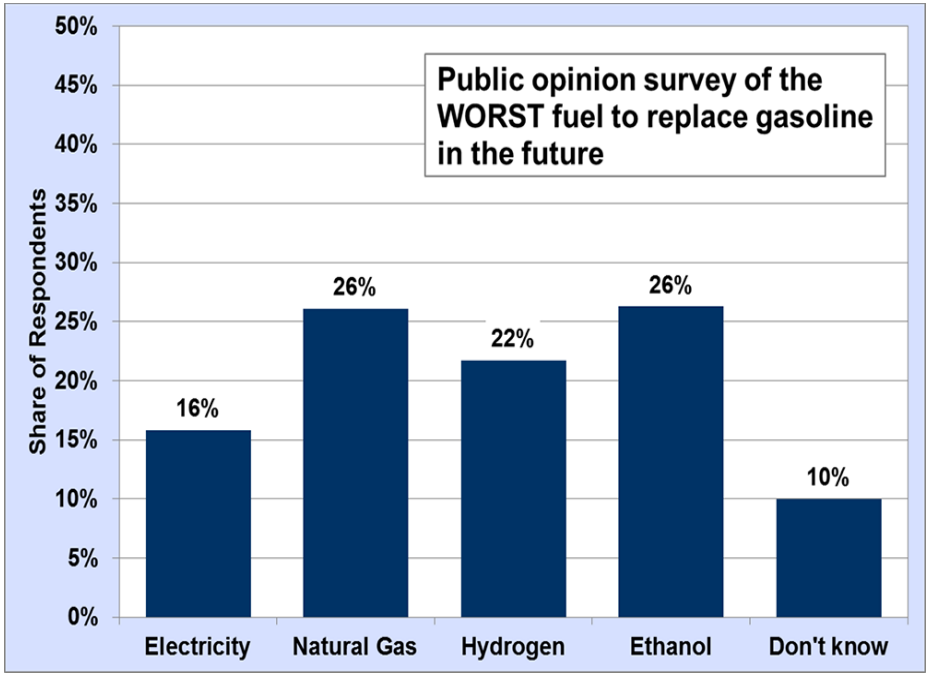


Source: http://energy.gov/eere/vehicles/fact-946-october-10-2016-driving-alone-private-vehicle-most-common-means

consumer sentiments

FOTW/NREL: Americans view electricity favorably as a future gasoline replacement





Source: http://energy.gov/eere/vehicles/fact-944-september-26-2016-public-opinion-fuels-which-could-replace-gasoline

consumer sentiments

KBB: Price and software concerns are largest psychological barriers for autonomous vehicle ownership

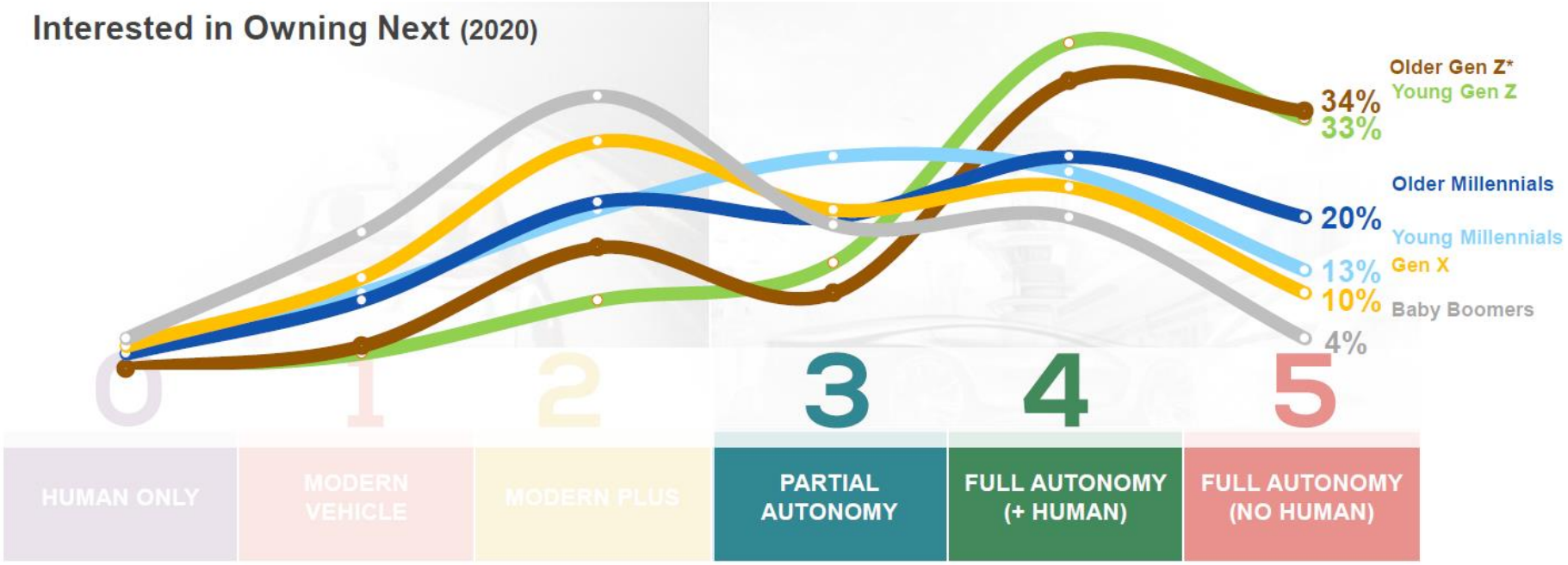
Barriers to Autonomy

	3	4	5
More expensive than can afford	47%	51%	50%
Expensive to fix	44%	46%	48%
Software hack	40%	41%	44%
Software/computer crash	39%	42%	47%
Trust myself to drive more than technology	31%	33%	38%
Concerned about interaction between AV & Non-AV	31%	34%	37%
Can't fully relax	28%	26%	27%
Fearful of vehicles not communicating well	28%	32%	37%
No option to drive	13%	14%	43%

Source: http://mediaroom.kbb.com/future-autonomous-vehicle-driver-study

consumer sentiments

KBB: Younger generations far more interested in owning fully autonomous vehicles

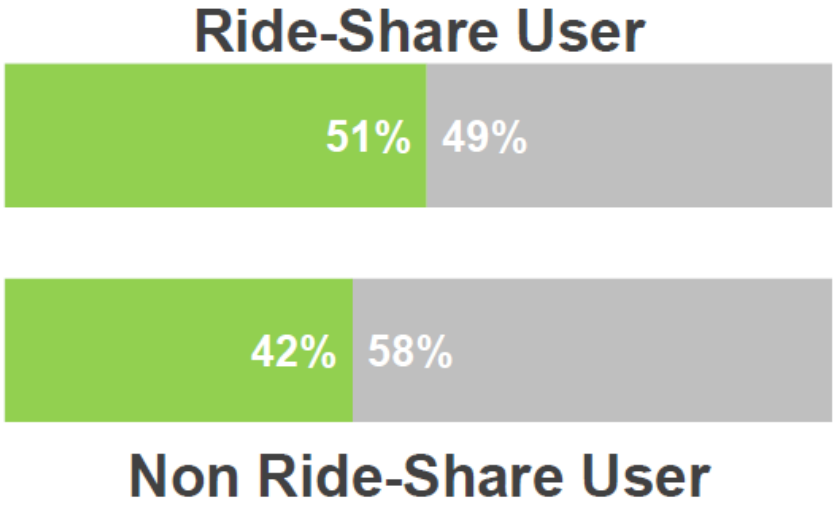


Source: http://mediaroom.kbb.com/future-autonomous-vehicle-driver-study

consumer sentiments

KBB: Ride-hailing users are more comfortable with fully autonomous driver than others are

I would prefer to use services such as taxis, Uber or Lyft with **self-driving vehicles**



I would prefer to use services such as taxis, Uber or Lyft with **human drivers**

Ride-Share Users are **significantly more comfortable letting a vehicle drive** them without their control versus Non Ride-Share Users

44% vs. **34%**

Ride-Share Users *Non Ride-Share Users*

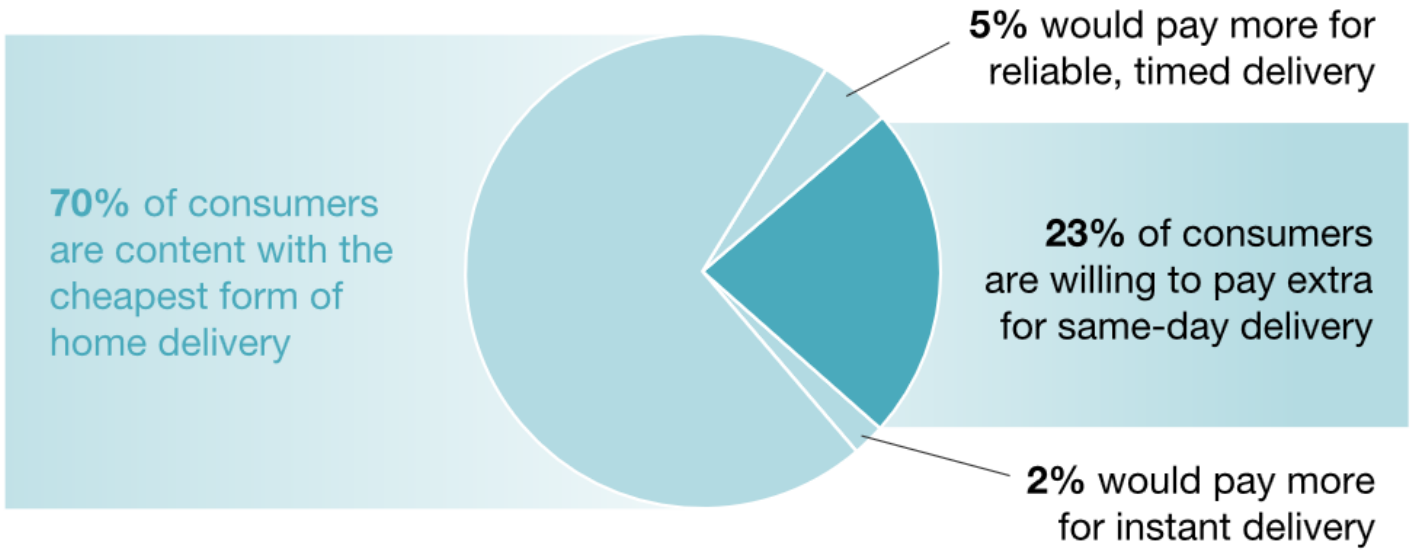
Source: http://mediaroom.kbb.com/future-autonomous-vehicle-driver-study

consumer sentiments

McKinsey: Nearly three-quarters of consumers are satisfied with the lowest cost shipping option

About a quarter of consumers would pay a premium for same-day delivery.

Delivery-model customer preferences, %



McKinsey&Company

Source: http://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/how-customer-demands-are-reshaping-last-mile-delivery?ReillyBrennanFoT

topics

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policy

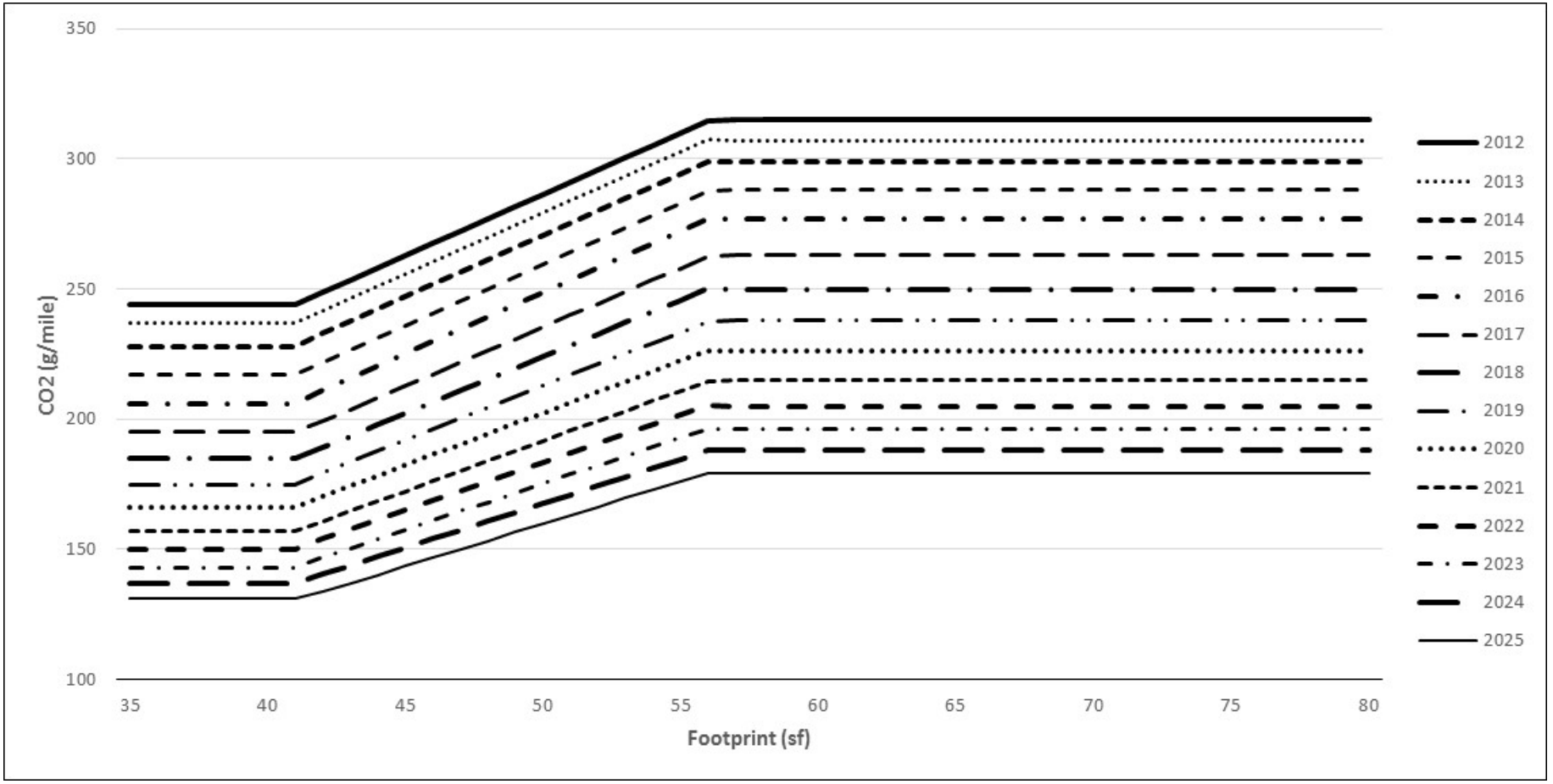
> EPA: Light-duty emissions standards for review
> EPA/NHTSA: Phase II standards for MDV and HDV finalized
> GAO: RFS standards not likely to meet GHG targets

future mobility

> BNEF: Investments in shared mobility companies rapidly growing
> BCG/Labs: CAVs can reduce cost per passenger mile

fuel economy

EPA: Adjudicatory determination that emissions standards to be as previously proposed for 2022–2025



Source: https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas-ghg

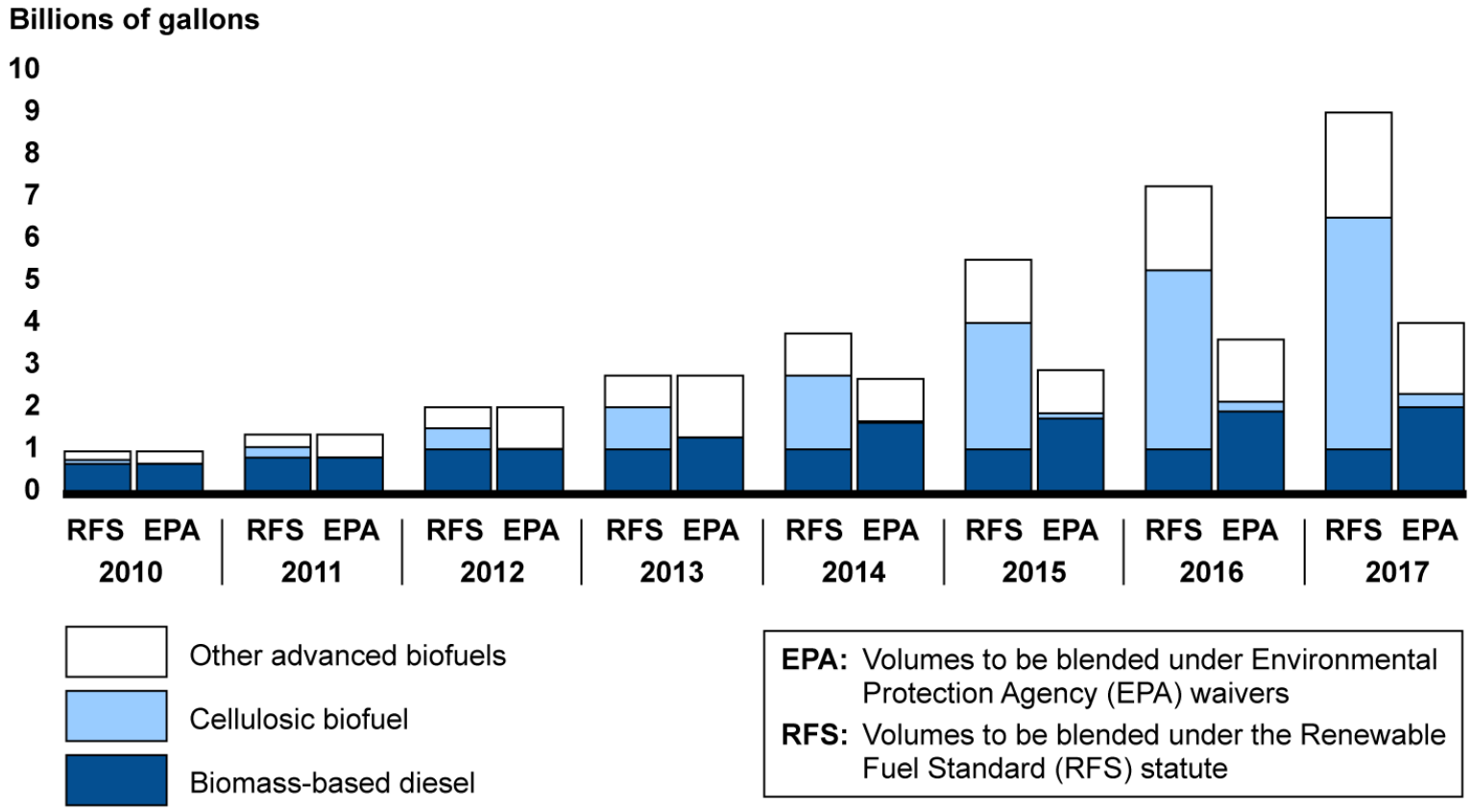
phase II standards

FOTW: Medium- and heavy-duty fuel efficiency and GHG standards set through MY2027

Source: http://energy.gov/eere/vehicles/fact-952-november-21-2016-nhtsa-and-epa-finalized-medium-and-heavy-truck-fuel

biofuels

GAO: RFS standards unlikely to reach targets for reducing greenhouse gas emissions due to slow uptake of cellulosic and other advanced biofuels

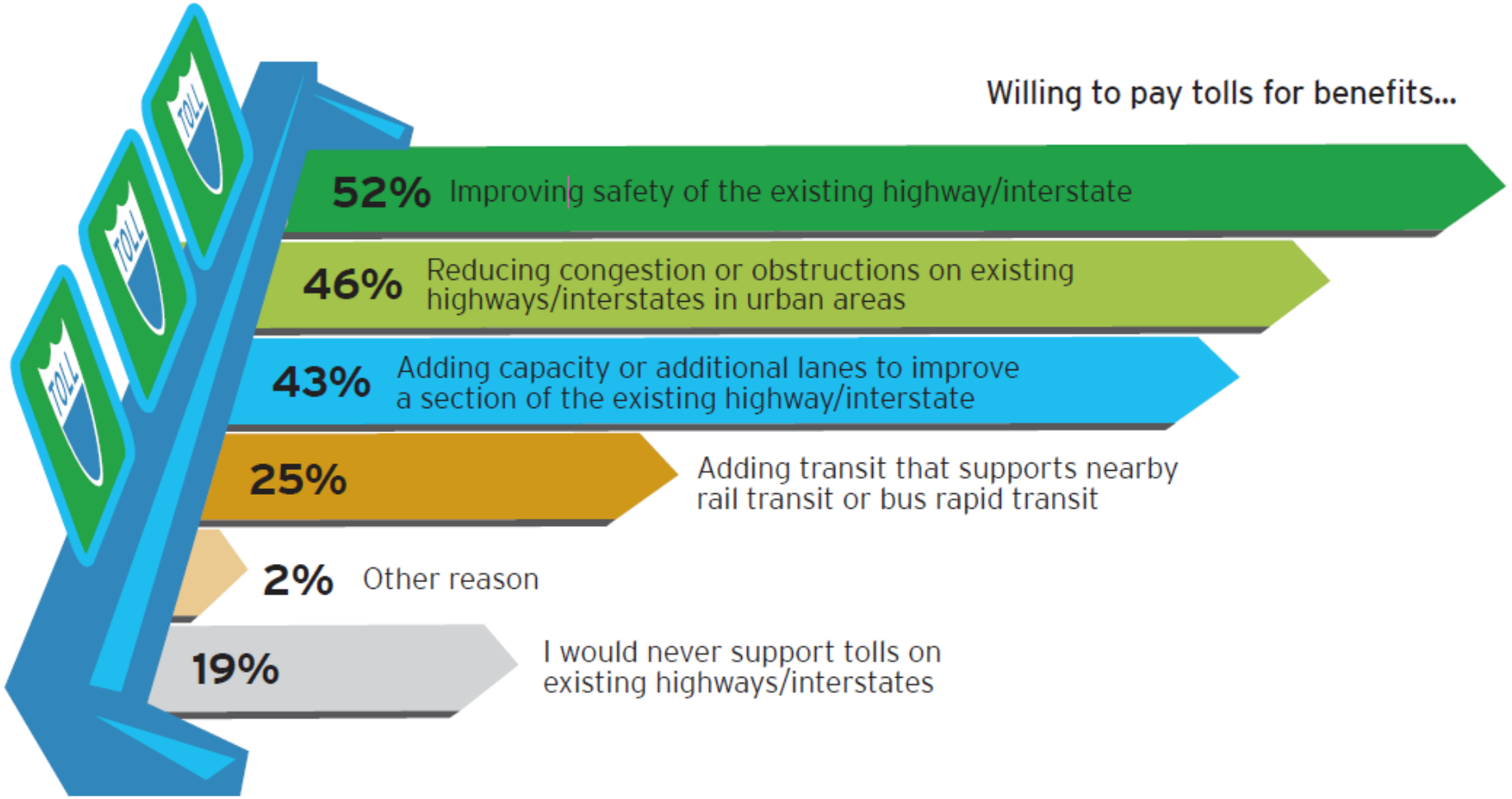


Source: GAO analysis of legal requirements and EPA data. | GAO-17-94

Source: http://www.gao.gov/products/GAO-17-94

tolls

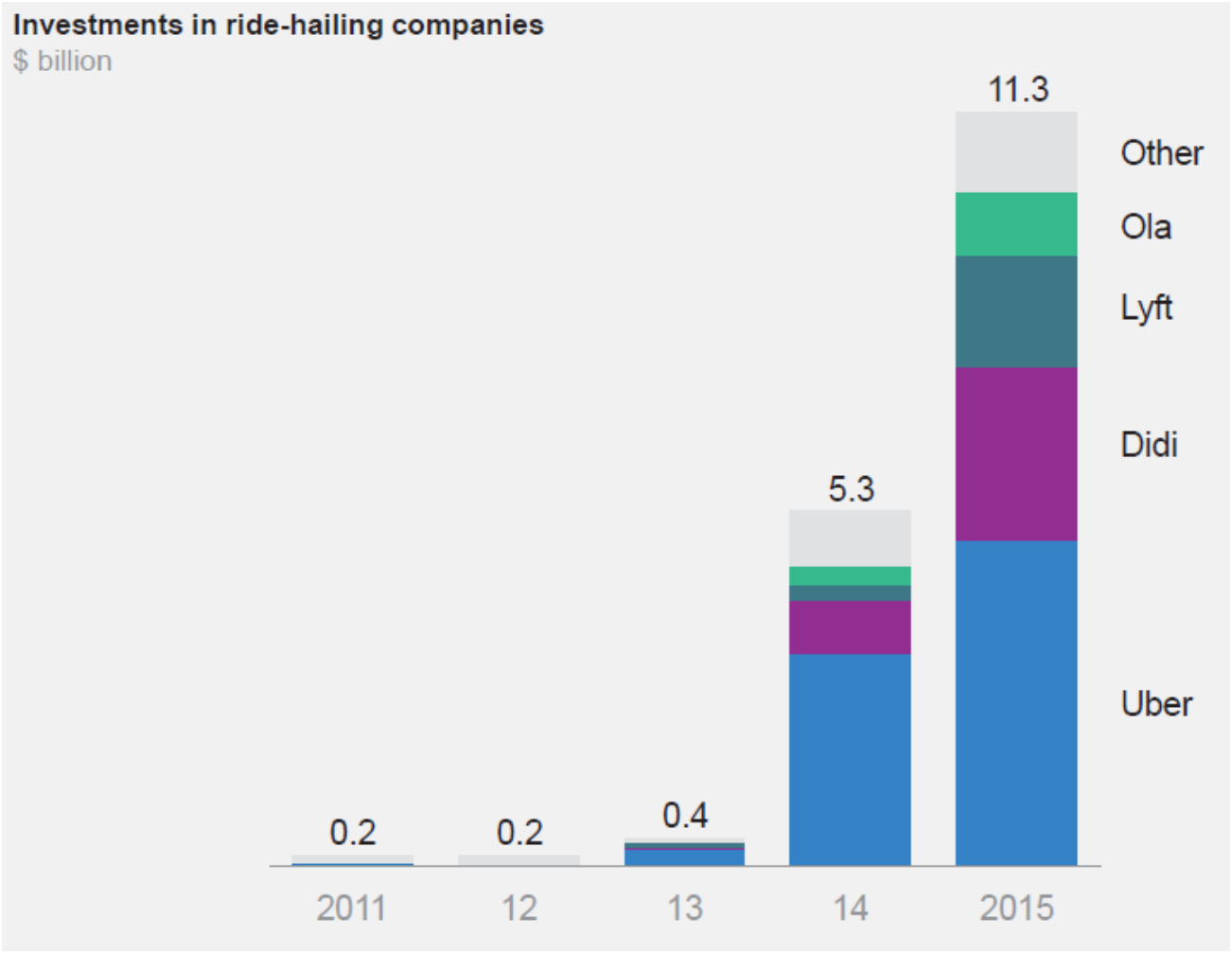
HNTB: Most people willing to pay tolls for a variety of reasons



Source: http://www.hntb.com/Newsroom/News-Releases/Highway-congestion-drives-support-for-tolls

future mobility

BNEF: Investments in shared mobility have taken off

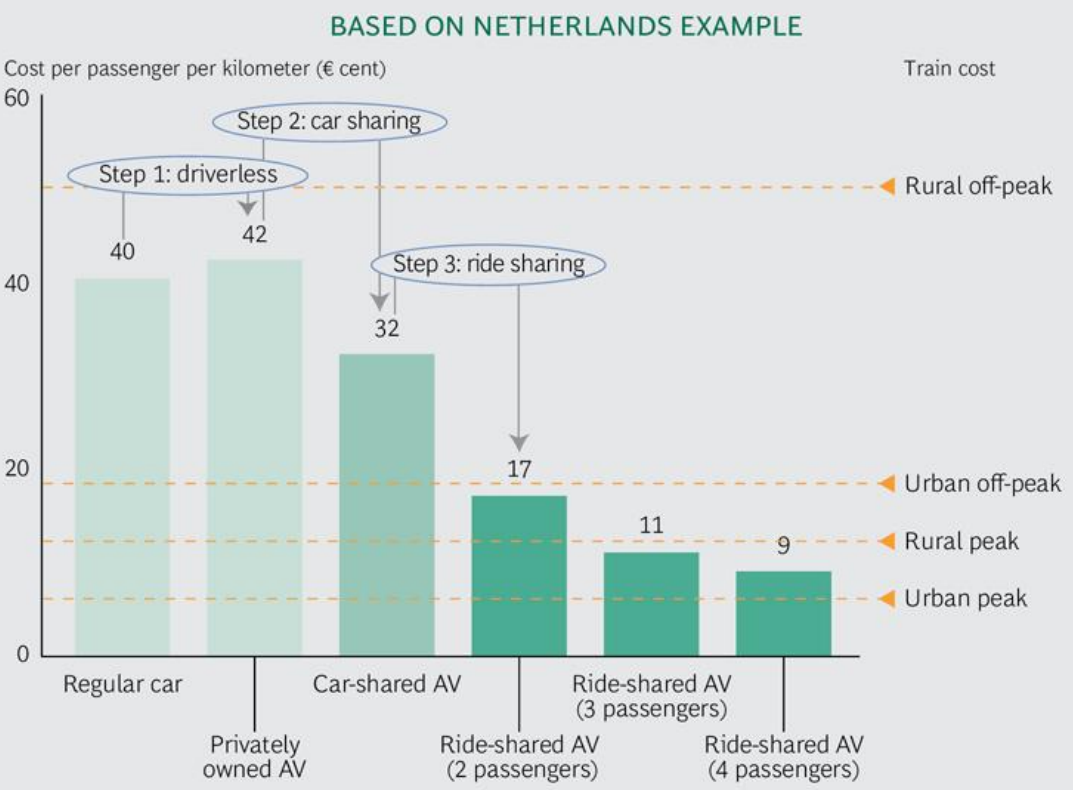


Source: http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/an-integrated-perspective-on-the-future-of-mobility

future mobility

BCG: Ride-shared automated vehicles can be cheaper than trains except for urban peak travel times

EXHIBIT 2 | For Urban Peak Travel Times, the Train Will Probably Remain the Least Expensive Option

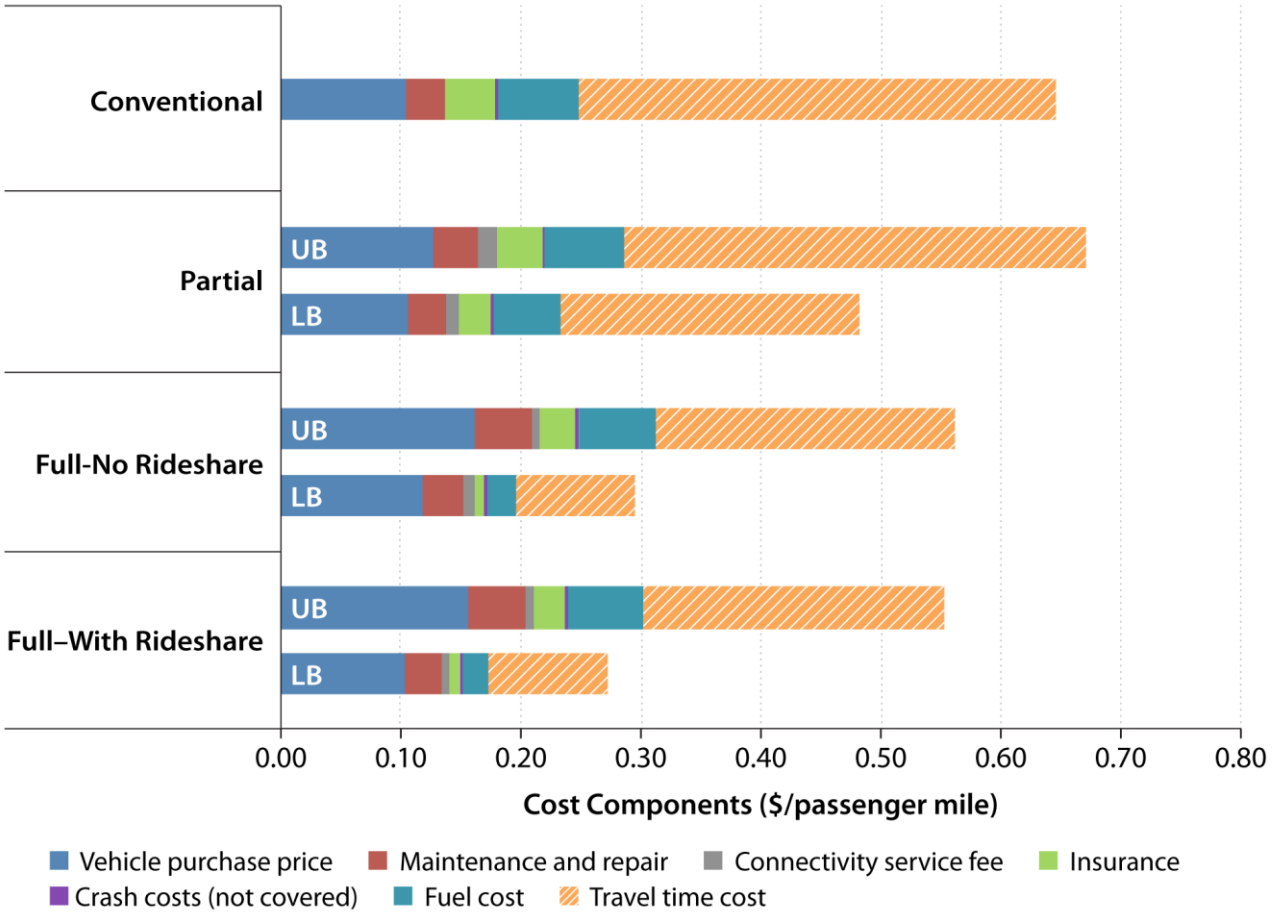


Source: BCG analysis.
Note: The data excludes state subsidies for rail infrastructure, so the full costs are substantially higher.

Source: https://www.bcgperspectives.com/content/articles/transportation-travel-tourism-automotive-will-autonomous-vehicles-derail-trains/

future mobility

ANL/NREL/ORNL/DOE: CAVs can potentially be cheaper per passenger mile than conventional vehicles



Source: http://www.nrel.gov/docs/fy17osti/67216.pdf

summary observations

energy Gasoline prices are still low; U.S. crude oil production lower than 2015 levels; OPEC planning to reduce production

automotive LDV sales historically correlated with good economy; U.S. EV sales above 500,000; EV sales up worldwide

tech/enviro Fuel economy at all-time high; CO2 emissions decreasing in U.S., flat worldwide; EVs typically cleaner than ICEs; CAVs may reduce (or increase) fuel consumption tremendously

opinion/policy EPA adjudication of LDV standards, MDV/HDV standards set; CAVs adoption/interest correlated to age; CAVs and shared vehicles may be cheaper than status quo

16.4
4Q 2016

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summary